

- 1 COMPLAINANTS' EXHIBIT No. 202. James D. Maher,
Commissioner.

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This certifies that a copy of the within report has been filed in the Mayor's office by the Metropolitan Sewerage Commission.

JAMES MATTHEWS,
Executive Secretary.

Preliminary Reports on the Disposal of New York's Sewage.

VI.

Study of the Collection and Disposal of the Sewage of the Lower Hudson, Lower East River, and Bay Division.*

Metropolitan Sewerage Commission of New York.

George A. Soper, James H. Fuertes, H. de B. Parsons, Charles Sooy-Smith, Lindsay R. Williams, Commissioners.
February, 1913.

- 2 *Preliminary Report VII.*

Study of the Collection and Disposal of the Sewage of the Lower Hudson, Lower East River, and Bay Division.

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*This report is issued in advance of the final report of the Metropolitan Sewerage Commission in order that the contents may be of early service. Some features of this report will remain open for revision until the final report is submitted.

3 *Study of the Collection and Disposal of the Sewage of the Lower Hudson, Lower East River, and Bay Division.*

Honorable William J. Gaynor, Mayor of the City of New York:

SIR: This report, the sixth in this commission's series of Preliminary Reports on the Disposal of New York's Sewage, is issued with the object of making public, at the earliest practicable date, this commission's studies as to the way in which it will be necessary to deal with the sewage of the fourth, and last of those divisions into which New York has been divided to facilitate the work.

While many details still remain to be considered, these studies show the general character of the works which should be constructed. To protect the Harlem and Lower East Rivers, large sewers are needed to intercept the sewage and carry it to an artificial island to be built near the outer limits of the harbor about three miles from shore; here, after a short and inoffensive treatment the sewage can be discharged into the ocean with confidence that the organic matters will be promptly rendered inert. All the rest of the sewage in this division should be passed through screens and grit chambers and discharged beneath the surface of the water in the main tidal channels.

1.—Boundaries and Topographical Features.

The territory in the Lower Hudson, Lower East River and Bay Division lies on both sides of the Lower East river, the west side of Manhattan and the east side of Upper New York bay. It extends from the extreme northwestern boundary of the city to below the Narrows.

It contains the largest population, and the most densely settled sections of any of the four divisions into which the commission has divided New York for the purpose of planning the main drainage and sewage disposal works which will be required. Within it lies the major part of the Boroughs of Manhattan and Brooklyn, which were separate cities until 1898.

This division is bounded on the east by a line which begins at Bensonhurst on Gravesend bay, runs in an irregular course northeasterly to Forest Park, in the Borough of Queens, and thence northwesterly to the East river near the mouth of the Harlem river. All of that part of Brooklyn and that part of Queens which lie to the west of this boundary line are included in the division.

4 Crossing the East river the boundary enters upon Manhattan Island at East Eighty-second Street, proceeds northwesterly to Central Park West, which it crosses at Ninety-first Street, and thence follows an irregular northerly direction along the height of land to the Harlem river at Spuyten Duyvil. That part of Manhattan, which lies to the south and west of the boundary so described, lies in this division. A small part of the division borders on the Hudson between Spuyten Duyvil and Yonkers. The west-

ern boundary of the division is formed by the Hudson river, Upper New York Bay, the Narrows and a part of Grave-end bay.

In the northern and southern parts of this division the topography is favorable to drainage, but there are large areas near the center which are so low and flat that the construction of sewers with sufficient grades to insure self-cleansing velocities and outfalls so situated as to provide for a free discharge at all stages of tide is impossible.

Made Land.—Many of the sewers in Manhattan feel the effect of the rising and falling tide for a considerable distance from the shores, in some instances, for over one mile. The worst cases of this kind are usually ascribable to the inadequate filling of low-lying or submerged areas as the beds of creeks and the once marshy shores of water courses. A remarkable regular shore line, made by filling in Manhattan, is shown on modern maps.

TABLE I.

Areas of Filled Land in this Division.

Borough.	Acres.
Manhattan	1,140
Brooklyn	1,520
Queens	460
Total	3,120

The filling has been largely, but not entirely, done along the water front. From 82nd Street on the Hudson river, southward, to the Battery, and thence northward along the Lower East river to 33rd Street, Manhattan, the marginal street is entirely on made land, the total length of shore so recovered being ten and one-half miles.

In many instances the made land extends some blocks back from the river front and in the neighborhood of Canal Street, Manhattan, it runs across the island, a distance of nearly two miles.

On the Brooklyn shore, the made land extends from a point north of Newtown creek to near 45th Street, South Brooklyn, a distance of eight miles. The Brooklyn Navy Yard is entirely on made land. A large area in the neighborhood of Red Hook and Gowanus canal, Brooklyn, has been reclaimed by filling.

The growth of made land has been gradual. It has increased with the increasing size of the city. The chief object in filling in the low-lying places has been to eliminate swamps and marshes and make the area of ground available for trade and commerce more extensive than originally existed. At the same time the filling has proved a convenient means of disposing of refuse.

If cellar earth and other suitable refuse material were utilized in filling in the swamps and meadow lands which exist in the outlying parts of New York City, the shore lines in parts of the harbor estu-

aries which are now seriously polluted would soon be straightened and the water would be more easily kept clean than under the existing circumstances.

To facilitate the filling in of the low-lying shores, the Harbor Line Board, composed of engineer officers of the U. S. Army, which has charge of maintaining the navigable channels of the harbor, has established lines for solid filling. These lines extend throughout the harbor and give a good idea of the plans to which future operations of filling will probably conform.

The land which lies in this division at elevations within twenty feet of mean sea level, includes all the filled land and also some additional areas mostly in Brooklyn and Long Island City. A broad belt runs from the head of Newtown creek to the vicinity of the Brooklyn Navy Yard. The total area below twenty feet elevation in this division is about 3.3 square miles in Manhattan; 6.5 square miles in Brooklyn and 2.9 square miles in Long Island City. Seventy-three per cent. of all the land in this division is of more than twenty feet elevation above mean tide. In Manhattan the high land lies for the most part near the center of the island. The highest point is somewhat above 100 feet, and is situated north of 77th Street. There is no point above sixty feet elevation further south than 33rd Street.

In Brooklyn the land, which lies at an elevation above sixty feet, exists chiefly in the eastern part of the division, where a well recognized ridge runs in a northeasterly direction from the vicinity of the Narrows. Elevations of 100 feet or more frequently occur on this ridge.

6 Tidal Range.—The difference between mean sea level and mean high water is one-half the mean tidal range as given in the Table II.

TABLE II.

Range of Tide in New York Harbor.

	Mean.	Spring.
Lower bay, Sandy Hook.....	4.7	5.6
Narrows, Fort Hamilton	4.6	5.6
Upper bay, Governor's Island.....	4.4	5.3
Hudson river, Spuyten Duyvil.....	4.0	4.8
East river, Hallett's Point (Hell Gate).....	5.5	6.6
East river, Throg's Neck	7.2	8.5
Harlem river, High Bridge	6.0	7.2
Kill van Kull, Shooter's Island.....	4.6	5.5
Newark bay, Passaic Light	4.7	5.7
Passaic river, Newark	5.0	6.0

Geology.—The superficial geological formation of this division is recent except for a small low-lying area of stratified drift in and near 125th Street. The surface of Manhattan island as far south as

23rd Street is composed chiefly of mica schist rock. South of 23rd Street, the rock disappears and stratified drift predominates.

In the Brooklyn part of this division, drift exists on each side of the central ridge, the ridge itself exhibiting the features of a terminal moraine with till on the western slope. Swamp and marsh lands exist to a limited extent, and then only in that part of Queens which lies in this division.

Value of Land.—The most valuable land in this division lies in the central and southern parts of Manhattan. It is a peculiar fact that whether for business or residence purpose, the most costly land lies along the center of the island. At the southern extremity is the financial district. North of this is the City Hall with the central post-office, numerous newspaper offices, the principal law courts and municipal administrative headquarters. Next above follows the wholesale dry goods center, then the region of retail shops, hotels and theatres and finally areas of high-class private residences and apartment houses which extend to the northern limits of this division. From this central zone east and west to the river front lie areas occupied by factories and residences, the latter ranging from modest dwellings to congested tenements.

In Brooklyn the water front is chiefly occupied by large factories and warehouses. The most crowded residence district and the center of financial administrative activity lies in that part of the borough which is opposite the southern end of Manhattan Island.

7 2.—The Existing Sewers—Their Outfalls and Resulting Nuisances.

Practically the whole of this division is sewered on the combined principle of sewerage.

In addition to the sewage which comes from the storm water of the streets and from the interior of the houses, the sewers of Manhattan and Brooklyn are required to carry away the water which falls upon the roofs, yards and courts of the buildings. The connections are trapped in order that the air from the sewers shall not enter the houses. The plumbing of the houses is ventilated by extending the soil pipes to the roofs.

In many cases, especially in Manhattan where the cellars of large buildings are deep, it is often necessary to pump the sewage into the street sewers. This is done at private expense.

Relief Sewers.—In most of Manhattan the sewers, which are large and short, have generally proved adequate to the requirements of the growing population; but in Brooklyn much trouble has been experienced from the insufficient provisions which were early made for drainage. The first sewers were built when the populations which they were required to serve were small and scattered, and when a comprehensive system of sewers was built between 1850 and 1860, the rainfall data were inadequate to permit designers fully to understand the requirements. With the increasing population the original sewers have been supplemented by large and expensive relief sewers, and these in turn have had to be assisted in some cases by the con-

struction of intercepting sewers for the collection and removal of storm water.

The sewers of Manhattan and Brooklyn are of many shapes and sizes. Among the older sewers of Brooklyn are many storm drains whose courses are not known. The older sewers are generally circular in shape, and when over twenty-four inches in diameter are of brick or concrete. Clay and cement pipe have been extensively used for the smaller sizes. Since 1907 the principles of design and construction have been much improved in Brooklyn.

Most of the sewer outlets on the Manhattan shores are between two and five feet in diameter, but there are some which have a section equivalent to a circle having a diameter of ten feet and more. The outlets on the Brooklyn shore are somewhat less numerous and some are larger than the largest of Manhattan, having a section equal to a circle with a diameter of fifteen feet.

Many of the sewers of Manhattan were built many years ago. They represent various periods of growth due to the introduction of public water supplies and other causes and have been extensively reconstructed and repaired within recent years.

Throughout this division the sewers are provided with catch basins at the street corners which were intended to convey the storm water from the gutters and protect the sewers from grit and other solid substances.

Ventilation.—It was intended that the sewers throughout this division should be ventilated through perforations in the manhole covers located at frequent intervals in the street. In most parts, notably in the older sections near the water front, the ventilation is defective, partly as a result of the settlement of the sewers, the entrance of tide water and the submergence of the outlets. Nuisances frequently result where steam and hot water are discharged into the sewers, since hot vapors rise and issue through the manhole covers disseminating odors of cooked sewage.

Outlets.—The outfalls of the sewers of this division, as elsewhere in the metropolitan district, are located at the bulkhead or shore line or, frequently in Manhattan, near the outer ends of the docks and piers.

The submergence of the sewer outfalls, as at present, and the rising of the tide drive the foul air into the streets and produce coatings of grease and solids upon the sides of the sewers, and this interferes with the flow of sewage. So much deposit is produced in some of the sewers that a cleaning gang, working continuously, can make no appreciable reduction in the depth of the deposit. Congealed grease has been found to measure as much as a foot in thickness in some of the sewers of Manhattan.

Physical Condition.—Inspections of the sewers made by the Metropolitan Sewerage Commission with the co-operation of the Bureau of Sewers and the Borough President of Manhattan have revealed many examples of distorted shapes, worn out invert, sunken arches, and cracks due to settlement. In many places irregular holes had been broken through sewers in making connections, and the holes never properly repaired. It was impossible to enter some of the

sewers for inspection owing to steam and hot water escaping from neighboring buildings. Other sewers could not be entered on account of the presence of illuminating gas in such quantities as to endanger health. In other areas, lanterns could not be carried into the sewers on account of gasoline vapor, presumably from automobile garages or other establishments using this explosive compound.

In Manhattan the sewers are inspected and cleaned only on complaint. The sewers are not flushed, but are cleaned by hand. Street sweepings are frequently pushed into the catch basins against orders in Manhattan and Brooklyn.

9 Catch Basins.—The effect of the catch basins is comparatively slight. They soon become filled with grit and other solid matters. To be of material use, they should be cleaned after nearly every storm. This is not done. The records for the year 1909 show an average of one cleaning for each catch basin in Manhattan every 5.3 months. This does not mean that all the 6,348 catch basins in the borough were cleaned. Some were cleaned out at comparatively frequent intervals and others were not cleaned at all.

In the year 1907 the catch basins in Brooklyn were cleaned on an average about $2\frac{1}{2}$ times a year and the quantity of deposits removed aggregated 35,272 cu. yds. The cost of removing this material was \$1.12 per cubic yard. The incompleteness and great cost of removing solid matter from sewage by the use of catch basins can be readily understood from these figures.

Large quantities of solid matters which pass the catch basins are deposited in the sewers themselves and are eventually removed by hand, washed out by the flood water of storms, or carried away through the alternate choking and flushing action which is produced by the rising and falling tide.

About 400,000 cubic yards of deposits are dredged each year from the slips and docks of that part of Manhattan which lies in this division by the Department of Docks and Ferries and large quantities are also dredged by private enterprise and from the Brooklyn shores. It is generally conceded that this solid material comes chiefly from the sewage. The water from which the deposits are taken is often black and offensive and gases of putrefaction rise in innumerable bubbles from the deposits at the bottom. During flood currents the sewage matters are driven back into the slips and in this quiet water some of the solid matters are deposited. On the outgoing tide grease and excreta are left adhering to the dock walls and piers. In the immediate vicinity of the outfalls the water is discolored and objectionable in appearance and odor. In some cases many acres are rendered turbid by the sewage.

Local Nuisances.—Extensive nuisances occur in this division at various points along the Brooklyn shores. Gowanus canal, Wallabout bay and Newtown creek are the most conspicuous. These bodies of water are actually large, although small in comparison with the great areas of the main divisions of the harbor. The condition of Gowanus canal, into which a 15-foot relief sewer as well as some eight other sewers ranging from $1\frac{1}{2}$ to $6\frac{1}{2}$ feet in diameter discharge, has been notorious for years. The water is black and

foul-smelling at all times and the sides of the piers, bulkheads and masonry structures are coated with deposits. As a means of improving this canal, the Borough of Brooklyn has constructed
 10 a flushing tunnel which leads from the head of the canal to an outlet in the Upper bay. Pumps force the water from the head of the canal through the tunnel, which is 6,270 feet long and 12 feet in diameter. The outlet is about 2 feet below low tide and is situated close to the shore between two long piers. The water in the vicinity of the outlet is strongly discolored when the pumps are in operation, the discharge from the tunnel being visible at times for a distance of more than a mile.

Wallabout bay in the Lower East river is polluted by a 9-foot sewer which discharges at the bulkhead line. The point of discharge is so protected from the tidal currents that a satisfactory dispersion of the sewage cannot take place. The bay is exceedingly offensive at all stages of tide, the bottom being covered with putrefying sewage sludge and the top with sewage apparently in an undiluted state. These objectionable conditions are in front of the New York Navy Yard.

Newtown creek, which empties into the Lower East river from a low-lying manufacturing district north of Brooklyn, is an offensive body of water. It supports a heavy traffic. Considerable quantities of manufacturing wastes are discharged into the creek from warehouses, elevators and factories, which line both banks. Some sewage empties into it, although the further pollution of this stream is prohibited by law. A 15-foot sewer, constructed through the joint action of the Boroughs of Brooklyn and Queens, empties into the head of Newtown creek and although this sewer was intended to accommodate storm water only, the dry weather flow being diverted, considerable pollution is ascribable to it.

There are no figures available to show the total cost of the sewers which exist in this division. It has been estimated that those of Manhattan exceeded \$26,000,000, and it is believed that those of Brooklyn have cost about an equal sum. There are about 522 miles of sewers in Manhattan and about 814 miles of sewers in Brooklyn.

3.—Possibility That the Sewers of Manhattan Will Have To Be Rebuilt.

It has seemed to those charged with the duty of maintaining the sewers of Manhattan, as well as to consulting engineers who have been called upon to examine into the subject, that it would eventually be necessary to reconstruct a large part of the existing sewers of Manhattan.

The chief reason for reconstruction lies in the need of repairs and the harm done to the sewers from the building of underground structures of various kinds, as, for example, passenger subways, conduits for electric light, telephone and telegraph and pipes
 11 for water, gas, steam and pneumatic mail service. As the city is entering upon extensive subway construction, it may be well to consider whether the interferences which now exist or are to be expected will not cause so much expense and make the

sanitary removal of the sewage so difficult that a reconstruction of the sewers will be a practical necessity. If the sewers are to be rebuilt, this fact should be known and preparations for it made at once so that such saving as can be effected in the cost of temporary alternations can be accomplished.

Right of Way of Sewers.—Of all the many structures beneath the city's streets, it is most important that the sewers should have the right of way. Unlike pipes for water, gas or electricity, which operate under pressure, sewers, whose flow is due alone to gravity must be laid to proper grade and alignment or they will not operate properly.

To be self-cleansing, sewers should maintain a certain velocity of flow and any reduction in the grade which checks the velocity will lead to deposits. Short turns and bends and changes in the cross section also alter the flow and interfere with the proper function of the sewer.

When it is remembered that sewerage systems should be well designed and constructed; that they are built under the ground in a manner which is intended to be permanent and durable; that they cannot be altered in size, shape, grade or location without harmful consequences; that their function is to carry off promptly and completely the most offensive and dangerous wastes of a city, the claim of the sewerage system for right of way beneath the streets appears to be fully justified. That this claim has not been respected is a regrettable fact. In defiance of the officials charged with the duty of maintaining the sewers, they have been moved from place to place, pierced and damaged in many ways. Instead of being used for the purposes for which they were built, the sewers have been abused by the discharge into them of harmful manufacturing wastes, hot water and steam and been rendered dangerous for inspection by the illegal emptying of gasoline and other inflammable compounds.

The structures which interfere with the sewers are located at depths which range from that of the shallow conduits which carry the current for the surface railways to that of the passenger subways. The passenger subways form a serious obstruction. They are situated as close to the surface of the street as practicable in order to facilitate entrance and exit and they require over 20 feet of depth. For the most part the subways, like the water, gas and other large mains run longitudinally through the island and the sewers in seeking their outlets to the rivers run perpendicularly to them.

12 **Interference from Subways.**—The first subway for passengers was built on a line which divided the sewerage systems of Manhattan into approximately two equal groups, the subway following along the axis of the island for most of its length. The interference with the sewers was, in this case, as slight as possible, it being feasible to cause the sewage to flow in many instances with but little alteration of the sewers to a convenient point of discharge to one of the nearby rivers on the east or west side of the island. But other subways which had been designed will run in lines nearly parallel to the first and will divide the sewers further. There will be no easy readjustment possible, as in the first case, for there will

be a central area which will be blocked off by the subways from the river on either side. In order to carry the sewage past these new subways, it will be necessary to make extensive reconstructions. It will be necessary to collect the sewage to more or less suitable points in the areas between the subway lines and then conduct it by siphons beneath the subway structure to points from which it can flow away by gravity. The alignment and grade of the sewers will, in many cases, be seriously interfered with. The siphons which should be capable of being emptied, inspected, repaired and cleaned, will be costly to build and, when of considerable depth, difficult to maintain. Sewage which now flows directly across the island will have to be diverted so as to run for considerable distances longitudinally, with the result that there will be a tendency to loss of velocity and formation of deposits in the drains.

Need of Repairs.—An important argument for reconstructing the sewers of Manhattan lies in the need for repairs. Inspections made by the Metropolitan Sewerage Commission have shown that some of the sewers, and especially the older ones, are in dangerous condition. Of 246 inspections, 38, or one-sixth, showed places where the sewers will have to be rebuilt within a few years on account of defective brick work alone. These locations exist along the whole length of the island. Of the 522 miles of existing sewers in Manhattan, 55 miles are seriously out of repair. To repair these, would involve an outlay which could more profitably be spent on new construction.

Separate vs. Combined System.—If the sewers were reconstructed, it is the opinion of many engineers that they should be built upon the separate system. Drains for storm water should be laid close to the surface of the streets and should be large and have ample grades to carry off much solid matter. When street washing, which is rapidly coming into favor, becomes general in the city, the quantity of grit and other solids to be removed by the sewers will increase. To a great extent the storm sewers should be made to carry off snow. Storm sewers should be built without catch basins at the street corners and should lead to central points where grit and
 13 other heavy materials can be removed before the sewage is discharged into the harbor. The elimination of the 14,000 catch basins which now exist would be desirable.

Sewers for house drainage should be laid so far beneath the surface of the streets as to permit the sewage to flow into them by gravity. They should be sufficiently deep to pass clear of all other subterranean structures. The comparatively small size which the sewers for house sewage would require would permit them to be located, even in congested streets, so as to give good alignment and grade. The sewage would thus be more promptly carried away than under present circumstances. In general these sewers would run perpendicular to the subways, crossing under them and delivering at suitable places into interceptors for conveyance to sewage disposal works or pumping stations.

Objections Against Reconstruction.—The objections to the reconstruction of the sewers of Manhattan lie in the expense and incon-

venience which the reconstruction would directly and indirectly entail upon the public. Almost all the streets of the city would require to be opened and the large quantities of earth and materials of construction would have to be handled without stopping vehicular traffic where the alterations were going on. The plumbing of over 150,000 houses would require to be altered so that the proper sewer connections could be made.

It is not clear how the storm water sewers, which should be laid close beneath the surface of the streets could escape the underground trolley conduits above, and the passenger subways beneath, in the longitudinal highways. There should be no siphons on these storm water drains.

Storm Water.—If the house sewage and storm water were collected separately, the disposal of the sewage would be facilitated, provided the storm water was not treated also.

It is not customary for cities to build works to treat all their storm water. The volume is so great, even when moderate falls of rain occur, that the works required to purify all the storm water would be excessively large and costly. There is, moreover, a general belief that the waste water from the roofs of houses and from the streets does not contain enough putrescible material to add materially to the pollution.

The literature relating to the treatment of storm water shows that experts generally consider that storm water from closely built-up cities is capable of producing at least as much offense as house sewage. There is reason for believing that the first flush of storm water is worse than even the relatively concentrated sewage of European cities, and that it is therefore desirable to treat a portion of the storm water.

14 **European and American Sewage.**—Much of the recorded information and opinion which exist with respect to the polluting effects of storm water is based upon European conditions, where the quantity of sewage at times of dry weather may amount to 20 or 30 gallons per capita per 24 hours. If the quantity of sewage in American cities is taken at 120 to 180 gallons per capita, it is evident that the argument for treating storm water has more weight in America than it has abroad, for if storm water is as bad as domestic sewage when the latter is concentrated to the extent of 20 or 30 gallons per capita per day, it must be about six times as bad when the domestic sewage is so dilute.

The aggregate weight of solid matter carried by storm water is very great. Analyses can be quoted which show that the percentage of suspended matter is several times as high in sewage containing storm water as it is in purely house sewage. This being so, and it being remembered that the volume of sewage is greatly increased at times of storm, it follows that the total amount of suspended matter carried by a given volume of storm water is much greater than the analyses indicate.

Numerous experts have expressed the opinion that careful attention should be given to the polluted character of the first flush of storm sewage. In the opinion of Samuel Rideal, whose familiarity

with the chemical and biological composition of sewage and whose knowledge of current practice in England entitles him to be regarded as an authority, "whatever system be adopted, the raw storm water of populous districts should never be allowed to pass in large volumes at the beginning of a storm directly into a stream." Dr. Dunbar, Director of the Hygienic Institute at Hamburg, and an authority on sewage disposal on the Continent of Europe, as well as in England, says: "It must not be supposed that the contents of rain water sewers are in general not so polluted as ordinary sewage. In busy districts, the washings from the streets, even if these are thoroughly cleaned daily, are everywhere found to be worse in every respect, including putrescibility, than ordinary sewage. Dr. Houston, the celebrated English bacteriologist, says that storm water is as "potentially dangerous to health as normal crude sewage." To these opinions many more could be added to the same effect.

American Analyses.—There is scant information on record to show the composition of storm water in American cities, although some data are available to indicate the average composition of sewage containing the combined drainage of houses and streets. This information is not as valuable as it would be if it had been collected with the intention of showing the difference in composition which occurs in the sewage of a given city during dry weather and at periods of storm, but some facts exist with respect to this subject.

15 At a testing station, established at Gloversville, N. Y., at which analyses were made continuously for about one year, 1908-1909, the marked effect of storm water upon the dry-weather flow was shown in the following manner. Following a period of dry weather, rain fell for practically 24 hours on June 5 and the flow of sewage increased 31 per cent., although comparatively few storm-water drains were connected with the sewers. The storm water came chiefly from the roofs of houses and from the streets. The strength of the sewage increased as follows:*

Total suspended solids from 312 to 622 parts per million, or 166 per cent.

Volatile suspended matter from 196 to 254 parts per million, or 73 per cent.

Fixed suspended solids from 116 to 368 parts per million, or 324 per cent.

It is worth noting that the largest increase in suspended matter was due to non-volatile, fixed or mineral matter. This suggests that storm water is peculiarly susceptible of improvement by settlement, an inference which is not strictly correct, for the removal of mineral matter would not produce nearly as much benefit as the removal of organic or nitrogenous matter. A large part of the suspended matter is grit.

The average composition of the combined sewage of some American cities, as determined by numerous analyses made at investigating laboratories, is indicated in Table III.

* Report to the City of Gloversville, N. Y., by Eddy and Vrooman, Aug. 7, 1909, p. 57.

TABLE III.

Composition of Sewage at Various Testing Stations.

(Parts per Million.)

	Suspended solids.			Nitrogen as			Oxygen consumed.			Cl.	Fas.
	Total.	Fixed.	Volatile.	Organic.	Free Am.	Nitric.	Total.	Sus.	Ins.		
1. Boston, 1903-5 .....	...	...	...	...	18.5	.19	43.1	19.3	23.8	...	...
2. Boston, 1905-7	135	44	91	9.1	13.9	.60	56.0	13.0	43.0	...	...
3. Columbus, 1904-5	200	130	70	9.0	11.0	.80	51.0	25.0	26.0	65	25
4. Waterbury, 1905-6	165	50	115	14.8	7.8	1.52	46.0	20.0	26.0	48	26
5. Gloversville, 1908-9	406	177	229	23.0	12.0	.38	95.0	50.0	45.0	158	48
6. Philadelphia, 1909-10	189	69	120	0.3	4.0	.23	76.0	...	40.4	39	28

16 In each of the investigations whose results are indicated in the foregoing table, an effort was made to obtain results which would be helpful in the design of works for the purification of the sewage. Certain peculiarities were thought to exist in the sewage to be dealt with which it was necessary to determine and the amenable-ability of the sewage to purification was tested in each case.

It will be observed that the sewages tested at the experiment stations varied considerably in the amount and nature of the suspended matter, as well as in the dissolved impurities. If partial treatment only had been thought sufficient, it would not have been necessary to make the analyses so complete. So far as the general character of the average sewage dealt with is concerned, the figures given are satisfactory, but they should be employed with caution in forming an opinion as to the composition of the sewage of other cities where importance attaches to questions of detail.

Opinion With Respect to Manhattan and Brooklyn.—Should the house and storm sewage of Manhattan be collected in separate systems, it would be desirable certainly to treat all of the one and perhaps part of the other. This could not conveniently be done in the same plants. Should both house and storm sewage be collected by the combined system, the treatment works should be so designed as to deal with the dry-weather flow and have enough more capacity to take care of the heavily polluted water which would be washed from the streets and houses with the first flush of the rain. It would be well to have the capacity of the main sewers and disposal works equal to twice the average dry-weather flow.

4.—Quantity and Composition of the Sewage.

The quantity of the sewage produced in this division can be estimated from a knowledge of the water consumed and the rainfall. But few of the sewers have been gauged and exact measurements of their flow are not available. As compared with many cities, especially those of Europe, the volume of sewage is large and its composition variable. It is, for the most part, remarkably fresh when discharged, owing to the short distance, and consequently brief time, consumed in passing from the houses to the outfalls.

The conditions of residence and manufacture are various in this division and the sewage which reaches the outfalls is correspondingly variable. The quantity produced is different at different hours of the day and night; and it is not the same at all seasons of year. Owing to the fact that most of the sewers for some distance from the shores of the harbor are choked with tidal water, the sewage is often mixed with salt water before it is discharged. In some cases
17 the sewage is warm with the waste water and hot water which is discharged from large office buildings, hotels and manufacturing establishments.

At times of rain much polluting water is washed from the streets. The quantity of this material is doubtless increasing, due to the more extended practice of washing the streets with water. After snow storms, snow is, to some extent, discharged into the sewers and with

it more or less solid matter, which was either present on the pavements before the beginning of the storm or is thrown out after the snow begins to fall.

In the report of the Metropolitan Sewerage Commission, dated August, 1912, pp. 28-30, is given an estimate of the composition of the sewage and the quantities produced in various parts of the metropolitan district. The composition is based on an ideal sewage whose constituents are stated. It is shown that about 625 tons of fecal matter is discharged into the harbor every day. Assuming the population in the year 1910 to have been 6,423,635 for metropolitan New York and New Jersey, and supposing that 90 per cent. of this number were connected with the sewers, the total number of persons contributing to the pollution of the waters would have been 5,780,000. The aggregate quantity of polluting matter estimated as dry solid material which was discharged in the year 1910 would have been 266,000 tons. About one-half of this was capable of putrefaction or already advanced to some extent toward that condition when discharged.

Assuming one ton of dry suspended matter to be equivalent to about 45 tons or about 53 cubic yards of wet sludge, it appears that the population of the metropolitan district empties into the harbor each year the equivalent of 12,000,000 tons of sludge, having a bulk of about 14,000,000 cubic yards.

Data relative to the population and sewage flow in different parts of the metropolitan sewage district, including the waters of this division, are given in Tables IV and V.

The Tables.—The eight divisions into which New York harbor has been separated for purposes of study have been described in the commission's report of August, 1912. To these is here added a ninth, to include the sewage which is naturally tributary to the Passaic and Hackensack rivers.

In preparing Table I, the dry weather flow of sewage discharged into each division has been assumed to be the same as the volume of the public water supplies of the areas tributary to the respective divisions. Where future quantities are considered, the sewage to be expected is in most cases based on the estimate of the authorities who are charged with the duty of providing the public water supplies.

The populations for 1910 have been taken from the United States census reports; those for 1940 are based on carefully made estimates by this commission, revised with the latest information obtainable.

TABLE IV.

Populations and Volumes of Sewage Directly Tributary to the Several Divisions of the Harbor.

Division of the Harbor	Sewage, Mgal's	Year 1900.			Year 1901.		
		Population	Gallons per capita per day.	Sewage Mgal's	Population	Sewage Mgal's	Gallons per capita per day.
Harlem River		522,000		70	520,000	156	
Manhattan		577,000		29	543,000	97	
Bronx							
Hudson river		767,000	124	99	1,708,000	253	148
Manhattan		720,000		98	1,476,000	258	
New Jersey		287,000		24	470,000	64	
Upper East river		1,000,000	131	132	1,940,000	262	156
Bronx		156,000		17	452,000	63	
Queens		36,000		4	197,000	56	
Lower East river		182,000	115	21	649,000	96	102
Manhattan		1,087,000		144	1,170,000	189	
Queens		60,000		6	283,000	22	
Brooklyn		915,000		94	1,670,000	213	
Upper bay		2,058,000	129	264	3,227,000	424	141
.....		519,000	123	64	968,000	118	139
Newark bay		18,000		1.3	51,000	7.1	
Bayonne		6,000		0.8	8,000	1.1	
Jersey City		67,000		16	113,000	18	
Newark		12,000		1	29,000	3.6	
Elizabeth							
Kill van Kull		167,000	136	13	200,000	30	150
Bayonne		27,000		1.8	64,000	9	
Richmond		27,000		5	75,000	14	
.....		285,000	9.00	7	1,293,000	279	9.00

Pamunkey bay	Brooklyn	570,000	...	610,000	180
Queens	Queens	81,000	...	210,000	...
Pascale and Hackensack rivers	New Jersey	351,000	151	900,000	184
Totals .....	.....	950,000	137	1,500,000	...
		0,019,000	...	11,570,000	...

• Million gallons per 24 hours.

From Table IV it will be seen that the total quantity of house sewage tributary to the harbor in the year 1910 was 765,000,000 gallons per 24 hours, and the population supplying this sewage was 6,019,000. By 1940 the population will be almost doubled and the quantity of sewage will be more than doubled. The sewage expected in 1940 in one day will be enough to fill a reservoir one square mile in area and 10 feet deep.

A glance at Table IV shows that a proportionate burden of pollution is not placed upon each division. The Lower East river receives much more sewage than any other division in comparison with its size. This will be true, also, in 1940, if nothing is done to prevent it. At that time over one-fourth of the total amount of sewage produced in the metropolitan district will be directly tributary to this stream. The increase which will go to this division from Brooklyn and Queens will be about half the quantity which was produced by Manhattan in 1910.

Table V has been made from data contained in the report of this Commission dated August, 1912. Of particular interest are the suspended organic and volatile matters.

TABLE V.

Assumed Composition of the Sewage which is Tributary to the Harbor on the Basis of 100 Gallons per Capita per 24 Hours. The Quantities are Expressed in Parts by Weight per Million of Water.

Solid Matters	800	Nitrogenous	150
Dissolved	500	Nitrogen	15
Suspended	300	Non-Nitrogenous	250
Organic and Volatile Mat-		Fats, etc.	50
ters	400	Total Carbon	200
Dissolved	200		
Suspended	200		

5.—Impossibility of Disposing of All the Sewage Through Dilution With the Harbor Water.

The discharge of sewage into a natural body of water is properly termed disposal through dilution. Dilution aids in the disappearance of the sewage, but it is only one of a number of factors which must come into play before the solid and liquid ingredients can permanently disappear.

Oxidation Essential.—For the disposal of sewage to be permanent, it is necessary that the decomposable ingredients shall be transformed into other and simpler chemical compounds. These transformations involve physical, chemical and bacteriological reactions. The final and indispensable change is really one of combustion; oxygen is absorbed and the substances which were offensive, or likely to become so; are mineralized. In this state and by this process alone do they become inert and incapable of producing offense.

20 It is the aim of all processes of sewage purification to oxidize the decomposable ingredients or prepare them for oxidation. In the land treatment of sewage, the ingredients are oxidized near the surface of the ground. In sprinkling filters and contact beds, oxidation is accomplished by bringing the sewage into intimate contact with the air on the surface of broken stones. The effect of dilution is to bring the liquid and solid particles of the sewage into contact with the oxygen which is dissolved in the water. In all these processes the end is essentially the same. Oxidation is the object aimed at.

In treating sewage by disposal upon land, in filter beds or in water, the sewage should be freed from its gross suspended solids before it is subjected to the final oxidizing process and if this is properly done, there is likely to be little trouble so long as the quantity of oxygen is sufficient and time enough is afforded for the oxidizing process to become complete.

If the ratio of sewage to oxygen is too great, serious consequences follow and this is as true when sewage is discharged into water as when it is passed through filters or placed upon land. The evil effects include discoloration, the evolution of foul smelling gases and the production of slimy, semi-solid deposits. Land and filters in this condition are said to be sewage-sick and water is popularly called stagnant. The condition is one of putrefaction.

Putrefaction is decomposition in the absence of oxygen. It postpones, but cannot replace, oxidation. Oxidation must eventually take place and if it does not occur promptly and under conditions which are within control, it will occur under such conditions as may accidentally and ultimately offer.

The Supply of Oxygen.—The exact amount of oxygen which should be supplied to sewage in order that decomposition should proceed at the most rapid rate or, at least, at a reasonably rapid rate is probably not determinable. The action is essentially a biological and chemical process in which time and temperature are important factors. The organisms which carry it on must be provided with all the oxygen which they need. It is impossible for them to have too much.

Clean water generally holds a large amount of oxygen. One thousand volumes made up of half sea water and half land water, uncontaminated with sewage and without decomposing matters of any kind, should have at 65 degrees Fahrenheit, 6 volumes of oxygen per litre or about 8.6 parts per million by weight. The harbor water in this division usually contains from two-thirds to one-half of what it should possess. The oxygen that has disappeared is the measure of the organic pollution.

Dilution Required.—As a result of observation and experiment in various parts of the world, engineers have formed opinions as to the amount of sewage which can safely be discharged into a natural body of water, such as an inland river or lake. The word safely here refers solely to the chance of producing a nuisance, chiefly odor. It has no relation to the effect which the sewage may have upon health.

According to the opinion of American engineers, the dilution must be in the proportion of at least 20 or 25 parts of water to one part of ordinary sewage and there may be conditions where a nuisance may result where the dilution amounts to nearly 50 parts of water to one part of sewage. When the proportion of sewage to water is greater than this, the capacity of the water is likely to be overtaxed. These supposedly safe ratios of dilution are based upon the assumption that the water with which the sewage is mixed is clean and possesses its normal amount of oxygen. Where the water is polluted to begin with the necessary dilution must be much greater.

In the Eighth Report of the Royal Commission on Sewage Disposal of Great Britain, issued at the end of 1912, it is recommended that where the dilution of sewage to water is between 150 and 200 times, the sewage should be purified so that the effluent will not contain more than 60 parts of suspended matter per million and that only when the dilution exceeds 500 times the volume of sewage should crude sewage be permitted to be discharged into a water course. These figures refer to English sewage, which is about 6 times as concentrated as American sewage, and to the water of inland rivers and lakes, but the Royal Commission holds the opinion that the proportions hold generally true for tidal waters also.

A glance at Tables VIII, IX and X of this report will show that the sewage in this division was not diluted with a proper amount of water in 1910, and will be still less adequately diluted in 1940 if measures are not taken to reduce the pollution.

It is worthy of note that the observations upon which American and English experts base their opinions have been made where sewage has been discharged into inland bodies of water. There has been no study of the discharge of sewage into tidal estuaries which would permit of safe ratios to be stated with positiveness for salt water. Such investigations as have been made indicate that sewage solids settle more rapidly in salt water than in land water, and it is believed that gallon for gallon, land water will dispose, in a normal manner, of more sewage than sea water.

It is not always clear how the dilution of sewage can be calculated in sea water. The same, or nearly the same, water often flows backward and forward for days near a sewer outfall, while the discharge of sewage is continuous. Under these circumstances the sewage flow

is irregular and its calculation is involved in uncertainty.

22 Errors which may be made in such calculations include the assumption that:

(a) The assumption that the flow of sewage is uniform during the 24 hours. It may vary as much as 50 per cent. at different hours.

(b) The flow of tidal water is uniform. It is quite the reverse. Aside from the fact that the currents at each turn must gradually slow down to the stopping point and then gradually increase to the normal strength of flow, winds, heavy rain, snow and intense cold may each produce a decided effect upon the volume of water moving in a harbor.

(c) The sewage matters become immediately and thoroughly mixed with the waters. The opposite is the fact. Dispersion and

diffusion are difficult to accomplish and consequently there are many kinds and degrees of stagnation.

(d) The sewage remains sewage after it is well mingled with the water. This is not true. Chemical changes at once set in.

(e) The waters into which the sewage is discharged are free from pollution to begin with. This assumption, however warranted in dealing with an inland river, is quite contrary to the fact as related to New York harbor.

The changes which sewage undergoes when it is discharged into a natural body of water should be carefully kept in mind, and the mistake, often made, of assuming that the sewage remains and can be reckoned with as sewage after admixture should be avoided. In no other way is it possible to obtain an accurate understanding of the subject. It is wrong to speak of sewage matters as sewage two or three hours after they have been discharged into a tidal estuary. Some of the original ingredients may still exist, but the chances are all against the continuance of any of them in an unaltered condition except the grosser solids and such others as may be able to persist in greatly diluted form.

Oxygen Required. It is impossible to say with any useful degree of accuracy how many pounds of oxygen one million gallons of sewage will require in order that the putrefiable ingredients may be rendered inert. The two ways of approaching this subject, that is, by analysis and incubation tests, are, unfortunately, too artificial to show what can reasonably be expected in nature. Predictions as to the amount of oxygen which would be present if a given quantity of sewage was to be discharged into a given quantity of water must, in the present state of knowledge, be considered unreliable.

But if it is impossible to calculate the oxygen requirements of sewage or express in percentages the proportions of sewage to water which may be present throughout a harbor, it is feasible to state, in at least approximate terms, the relation which exists between the volume of sewage and the volume of water present under various circumstances and such calculations may be of some value. They are likely to prove of greatest service when they are expressed in a simple way and are used with other data as a means of obtaining a general opinion of the case.

It was in this way, and with all the restrictions and qualifications which a knowledge of the situation imposed, that Prof. Adeney, in a report to the Metropolitan Sewerage Commission, calculated the dilution of sewage in New York harbor (See p. 95, Report Metropolitan Sewerage Commission, August, 1912).

Calculations of Dilution.—Taking his data from the published reports of the commission, Prof. Adeney calculated that about 59,400,000 cu. ft. of sewage flowed into the whole harbor during a tidal cycle of 12 lunar hours. Inasmuch as about 23 per cent of the water of the harbor flowed out on the ebb tide, the same percentage of the contribution of sewage would flow to sea at the same time, leaving about 77 per cent. mixed with the harbor waters at mean low tide. The quantity of liquid sewage matter subsequently remaining within the harbor would increase with each succeeding tidal

cycle until the quantity which passed out with the ebb tide became equal to that which drained into the harbor during the tidal cycle. This would occur when the total volume of liquid sewage, remaining intermixed with the harbor waters at mean low tide had become equal to about 195,500,000 cu. ft., which it would do after about 20 tidal cycles. The volume of liquid sewage matters passing out of the harbor through the Narrows would then continue to equal the volume of liquid sewage matters flowing into the harbor during a complete tidal cycle. That is, if 59,490,000 cu. ft. of sewage passed out of the harbor with each 12,310,000,000 cu. ft. of ebbing tide, the dilution of sewage to water would be in the proportion of 1 to 200 and the dilution to the liquid sewage matters remaining in the harbor at mean low tide would be in like proportion.

Both at the beginning and end of his calculation, Prof. Adeney took pains to fully explain that this calculation did not, as no calculation could, truly represent the facts.

In a report by Messrs. Black and Phelps, made to the Board of Estimate and Apportionment of New York in 1909, the question of dilution is dealt with at length, for it was believed to have an important bearing on the question of dissolved oxygen, and the authors considered that the oxygen should not fall below 70 per cent. of the amount which would be present if the water was saturated with it.

24 The sources of the water in each principal part of the harbor were assumed in accordance with volumes and velocities stated by the Coast and Geodetic Survey in 1886, and the proportion of water from each source was apportioned by the authors as, in their judgment, seemed correct. For convenience—these volumes were reduced to percentages of the whole and each was given a characteristic letter to facilitate computation. A series of equations was derived and the composition of the water of each part of the harbor was calculated for various tidal periods.

These studies were taken by the authors to indicate that the volume of pure sea water which entered the harbor between the Narrows and Throgs Neck every 12 hours was 29,135 million gallons and that this contained under summer conditions 1,946,218 pounds of dissolved oxygen. It was considered that if this oxygen were to be reduced by sewage to 70 per cent. of saturation, 583,865 pounds would be lost in 12 hours. The total volume of water in the harbor within the limits named was taken to be 251,418 million gallons, and it was stated that if this were reduced to 70 per cent. of saturation, it would absorb in 12 hours from the atmosphere 0.95 per cent. of its saturation value of 159,550 pounds.

The oxygen absorbed from the atmosphere plus the oxygen from the pure sea water would give a total of 743,415 pounds of oxygen. Finally, assuming that the sewage would be produced at the rate of 100 gallons per capita per day, the authors arrived at the opinion that the natural supply of oxygen would be sufficient to care for the sewage of a population of 7.4 millions, provided the sewage was discharged at the two ocean entrances.

6.—Ratios of Sewage to Water.

Some calculations of the ratios of sewage to water have been made by the Metropolitan Sewerage Commission which deal with comparatively small parts of the harbor and are consequently not greatly affected by the errors which are generally inseparable from such computations. But all calculations of this kind should be regarded as crude approximations of the truth.

There are three divisions of the water with which it is of interest to compare the sewage. First, the volume of water which is contained in the vicinity of an outlet at mean low tide; second, the volume of the tidal prism or quantity of water in the vicinity between the levels of low and high tide; third, the net ebb flow past the point where the sewage is emptied.

The Metropolitan Sewerage Commission has divided New York harbor into ten sections and the quantities of sewage which were discharged directly into these sections in 1910 have been estimated: the quantities of water in each section below mean low tide, in the tidal prism, and the net ebb flow through the section have
25 been computed and the ratio between the sewage and the water has been calculated. Calculations based on estimates of future quantities of sewage have also been made.

In addition to these computations, estimates have been made of the aggregate weight of sewage impurities which are tributary to each section. These calculations are based on a definite composition of the sewage which is assumed and taken to be uniform for the whole territory. The composition assumed is that of the standard sewage as shown in Table V. The volume of the sewage for the year 1910 is based upon the public water supply. The volume expected in future is also founded upon anticipations of the drinking water requirements. The per capita volume of sewage being stated, it will be possible at any time to correct the estimates of weight of impurities discharged into the harbor in case either the composition or volume of the sewage becomes known. It is improbable that such knowledge can be obtained until main drainage works are built.

It has seemed desirable to calculate the quantities of sewage material which would be discharged into the various sections of the harbor in case the sewage was first passed through works for the more or less complete removal of the impurities. The processes of treatment which have been thought most worthy of consideration in this connection are such as have been well established by experience. Screens are considered because of their compactness and ability to operate with varying quantities of sewage and small head. Settling basins have been included because of their almost universal employment in sewage purification works and their efficiency in removing suspended matter. Chemical precipitation has been considered because it is one of the most efficient means for removing both suspended and dissolved matter at one process. Sprinkling filters have been included, since they represent the most effective means of oxidizing the sewage impurities in a given area of land.

It would be feasible, and it is customary where a high degree of purification is required, to combine two or more of these processes in a given plant.

The least effective process which seems worth considering for the sewage which is to be discharged into the harbor is screening, and the highest degree of purification practicable in most cases in the territory where the sewage is produced in screening and rapid settlement. More purification than this would require a greater amount of land than is procurable except at great cost and involve probable nuisance from odors and flies.

Estimates of the quantities of sewage discharged into New York harbor show that all sections do not receive an equal share of pollution; the analyses of the water show that the circulation of the tide is insufficient to distribute satisfactorily the excessive burden which some sections receive. Some parts of the harbor are much more polluted than others, the region of greatest pollution being close to the most densely settled part of New York City. The Lower East river and Harlem receive large quantities of sewage from both shores.

TABLE VI.

Volumes of Water at Low Tide, in the Tidal Prism and the Net Discharge from the Several Divisions of the Harbor. The Quantities are Expressed at Million Cubic Feet.

Division of the harbor	Volume of water below mean low tide.	Tidal prism.	Net ebb flow in 12 lunar hours.
Harlem river	285	148	15
Hudson river, Battery to Mt. St. Vincent	12,330	1,697	1,087
Upper East river	5,512	1,869	.....
Lower East river	4,174	552	100
Upper bay	12,970	2,541	1,283
Newark bay	1,542	1,071	105
Kill van Kull	728	150	88
Jamaica bay	2,029	1,977	.....
	40,971	10,033	.....

Table VI was prepared partly from tidal data computed by this commission and partly from information supplied by the United States Coast and Geodetic Survey in 1909, as a result of studies which were made in response to this commission's request.

It will be seen from Table VI that the Upper bay contains more water at low tide, has a larger tidal prism and has a larger net discharge of water than has any other part of the harbor. The Hudson river is a close second in volume at low tide, but it has a smaller

prism and net flow than the Upper bay. The tidal prism and volume of water at low tide are nearly the same in Jamaica Bay and Newark bay, from which it appears that these bodies of water are almost half renewed at each tide.

In the Lower East river, the tidal prism is one-sixth the volume of water which lies beneath the level of mean low tide and the net ebb flow is about one twenty-seventh of it. Nowhere else in the metropolitan district is the net ebb flow so small in comparison with the tidal prism or volume of water at low tide. Large as is the volume of water

in this division, it is evident that there is not a great deal of new water passing through it. In the Harlem also, the tidal prism is large and the net ebb flow small when compared with the volume of water at mean low tide. From these figures, it appears that such refreshing action as the Lower East river and Harlem river receive is due to diffusion with cleaner water at the two ends of these streams and that little renewal occurs by actual displacement with water from a neighboring section. Large though the Lower East river seems to be and swift as are its currents, it has only one-tenth as much net ebb flow as the Hudson.

To facilitate computations which will be described later, the quantities of sewage discharged into the several divisions of the harbor have been converted from gallons per 24 hours to cubic feet per 12 lunar hours. The results are recorded in Table VII.

TABLE VII.

Volume of Sewage Directly Tributary to the Several Divisions of the Harbor.

Division of the Harbor.	Directly tributary, million cu. ft. per 12 lunar hours.	
	Year 1910.	Year 1940.
Harlem river	6.9	17.5
Hudson river	9.2	20.9
Upper East river.....	1.5	6.9
Lower East river.....	17.1	31.5
Upper bay	4.4	8.2
Newark bay	0.9	2.1
Kill van Kull.....	0.5	1.6
Jamaica bay	2.7	11.3

TABLE VIII.

Ratio of the Volume of Sewage Directly Tributary per 12 Lunar Hours to the Volume of Water in the Harbor at Mean Low Tide. The Quantities Given are in Millions of Cubic Feet.

Division of the Harbor.	Water in the division.	Sewage tributary to the division.			
		Year 1910.		Year 1940.	
		Volume.	Ratio.	Volume.	Ratio.
Harlem river	285	6.9	1:41	17.5	1:16
Hudson river	12,330	9.2	1:1350	20.9	1:590
Upper East river.....	5,512	1.5	1:3675	6.9	1:799
Lower East river.....	4,174	17.1	1:244	31.5	1:132
Upper bay	12,970	4.4	1:2920	8.2	1:1580
Newark bay	1,542	0.9	1:1680	2.1	1:740
Kill van Kull.....	728	0.5	1:1470	1.6	1:900
Jamaica bay	2,029	3.7	1:550	11.3	1:180
	30,570	44.2	1:806	100	1:306

28 Table VIII which is prepared from data contained in Tables VI and VII emphasizes the proportionately heavy sewage burden which is now, and in future would be, placed upon the Lower East river. The ratio of sewage to water at mean low tide which was 1 to 244 in 1910 would be 1 to 132 by 1940. A notably low ratio is that of the Kill van Kull which was 1 to 1470 in 1910 and would be 1 to 460 by 1940. This body of water received much of its pollution from neighboring bodies of water. The pollution of Newark bay will increase by direct contributions of sewage until the ratio which was 1 to 1680 in 1910 will be 1 to 740 by 1940 unless measures are taken to keep the sewage out of it.

TABLE IX.

Ratio of the Volume of Sewage Directly Tributary to the Volume of Water in the Tidal Prism. The Quantities Given are in Millions of Cubic Feet.

Division of the Harbor.	Water in the prism.	Sewage tributary to the division.			
		Year 1910.		Year 1940.	
		Volume.	Ratio.	Volume.	Ratio.
Harlem river	148	6.9	1:21.4	17.5	1:8.5
Hudson river	1,697	9.2	1:185	20.9	1:81
Upper East river.....	1,860	1.5	1:1246	6.9	1:271
Lower East river.....	552	17.1	1:323	31.5	1:17.5
Upper bay	2,541	4.4	1:570	8.2	1:310
Newark bay	1,071	0.9	1:1170	2.1	1:510
Kill van Kull.....	150	0.5	1:300	1.6	1:194
Jamaica bay	1,977	3.7	1:540	11.3	1:175
	10,165	44.2	1:229	100.0	1:101

Table IX has been prepared from Tables VI and VII and shows the remarkably small ratios which exist between the sewage and tidal prism in most of the divisions of the harbor. The smallest ratio occurs in the Harlem, 1 to 21.4, although the Lower East river, 1 to 32.3, is very low for the year 1910. In 1940 the tidal prism will be only $8\frac{1}{2}$ times the volume of sewage discharged directly into the Harlem and in the Lower East river only $17\frac{1}{2}$ times the quantity of sewage received.

Unlike the ratio of sewage to water below mean low tide, the relation of sewage to the tidal prism is comparatively large in Newark bay and will be considerable in 1940. This division of the harbor, which was comparable with the Lower East river in Table VIII, resembles the Hudson river, where the pollution is, and probably will remain, large.

The quantities of water passing through each division in their relation to the volume of sewage directly discharged are shown by Table X, which was prepared from Tables VI and VII.

TABLE X.

Ratio of the Volume of Sewage Directly Tributary per 12 Lunar Hours to the Net Ebb Flow. The Quantities Given are in Millions of Cubic Feet.

Division of the Harbor.	Net ebb flow.	Sewage tributary to the division.			
		Year 1910.		Year 1940.	
		Volume.	Ratio.	Volume.	Ratio.
Harlem river	15	6.9	1:2.2	17.5	1:0.85
Hudson river	1,087	9.2	1:119	20.9	1:52
Upper East river.....	.....	1.5	.....	6.9	.....
Lower East river.....	100	17.1	1:5.9	31.5	1:32
Upper bay	1,283	4.4	1:288	8.2	1:156
Newark bay	105	0.9	1:114	2.1	1:50
Kill von Kull.....	88	0.5	1:178	1.6	1:55
Jamaica bay	24	3.7	1:6.5	11.3	1:2.1
	2,702	44.2	1:61	100.0	1:27

The small amount of dilution from the net ebb flow which the sewage which was discharged into the Lower East river received in 1910 and will receive in 1940 is even more graphically indicated in this table than in its predecessors. By 1940 there will be more sewage discharged into the Harlem than there will be tidal water passing through that stream. There will be about three times as much tidal water as sewage passing out of the Lower East river. The Hudson river and Upper New York bay alone seem to be comparatively well supplied with water available for flushing purposes.

Table XI shows the number of tons of the various constituents of the sewage based on the composition shown on Page 18, and the volume shown on Page 27. It will be seen that in every important respect, the Lower East river receives a greater weight of contaminating matters than does any other division of the harbor, irrespective of its size. Next comes the Hudson river, followed by the Harlem. The total weight of sewage materials discharged into the Kill van Kull and Newark bay is small as compared with the quantities of polluting matters discharged into the Lower East river.

TABLE XI.

Solid, Organic and Volatile Matters Contained in the Sewage Directly Tributary to the Several Divisions of the Harbor, The Quantities are Expressed as Tons of 2,000 lbs. per 12 Lower Boats.

Division of the Harbor.	Year.	Sus- pended solid matters.	Organic and volatile matters.					
			Total.	Dissolved.	Sus- pended.	Nitro- genous.	Fat, etc.	Carbon.
Harlem river	1910	52	70	35	35	20	9	35
.....	1940	111	148	74	74	50	18	74
Hudson river	1910	65	87	43	44	31	11	43
.....	1940	126	168	84	84	63	21	84
Upper East river	1910	12	16	8	8	6	2	8
.....	1940	43	57	29	29	21	7	29
Lower East river	1910	133	178	89	89	67	22	89
.....	1940	299	279	139	140	105	35	139
Upper bay	1910	34	45	23	22	17	6	23
.....	1940	59	79	40	39	30	10	40
Newark bay	1910	7	9	4	5	3	1	4
.....	1940	13	18	9	9	7	2	9
Kill van Kull	1910	3	4	2	2	2	0.6	2
.....	1940	9	12	6	6	4	2	6
Jamniken bay	1910	23	30	15	15	11	4	15
.....	1940	59	79	39	40	30	10	39
Total	1910	329	430	219	220	165	55.6	219
.....	1940	629	849	429	429	318	105	429

Table XII, which has been prepared from Table V and VII, shows the weight of sewage ingredients which will be discharged into the harbor in 1910 and 1940, assuming that the sewage is first passed through certain forms of treatment with the object of removing impurities. The efficiency of the treatment employed has been assumed as follows: The screens remove 15% of suspended matter and 10% of organic matter; sedimentation 60% of suspended matter and 30% of organic matter; chemical precipitation 85% of suspended matter and 50% of organic matter; sprinkling filters 90% of suspended matter and 70% of organic matter.

It will be observed that the use of any of these processes would be beneficial, but that the residue to be discharged after screening or sedimentation would still leave very large quantities of polluting matter to go into the water. Chemical precipitation and the use of sprinkling filters would probably furnish all the relief needed for as many years as can now be anticipated. As has been shown elsewhere in this report, however, these latter processes are not applicable unless the sewage is carried to some point far removed from its present source for treatment.

TABLE XII.

Suspended and Organic Matters which Would be Contained in the Sewage Directly Tributary to the Several Divisions of the Harbor After Treatment. The Quantities Given are in Tons per 12 Lunar Hours.

Division of the Harbor.	Year.	Sewage after treatment.									
		Crude sewage.		Sewage.		Sedimentation.		Removal precipitation.		Sprinkling filters.	
		Sum.	Org.	Sum.	Org.	Sum.	Org.	Sum.	Org.	Sum.	Org.
Harlem river	1910	52	30	44	69	31	49	7.8	35	5.2	23
.....	1940	111	148	94	153	44	104	16.0	74	11.1	46
Hudson river	1910	65	87	55	78	36	61	9.8	44	6.5	26
.....	1940	126	168	107	151	59	118	18.0	84	12.0	50
Upper East river.....	1910	13	16	10	14	5	11	1.6	8	1.2	5
.....	1940	43	57	37	51	17	40	6.4	28	4.3	17
Lower East river.....	1910	133	178	113	160	53	125	20.0	90	13.3	53
.....	1940	266	279	178	251	84	195	31.4	140	20.9	84
Upper bay	1910	34	45	29	40	14	32	5.1	22	3.4	15
.....	1940	59	79	50	71	24	55	8.8	39	5.9	24
Newark bay	1910	7	9	6	8	3	6	1.0	4	0.7	3
.....	1940	13	18	11	16	5	13	2.0	9	1.3	5
Kill van Kull.....	1910	3	4	3	4	1	3	0.5	2	0.3	1
.....	1940	9	12	8	11	4	8	1.4	6	0.9	4
Jamaica bay	1910	37	59	29	57	19	37	3.4	15	2.3	9
.....	1940	80	79	50	71	24	55	8.8	40	5.9	24
Total.....	1910	329	439	290	394	132	308	49.4	210	32.9	131
.....	1940	626	849	535	735	252	568	94.3	426	62.9	252

7.—Possible Methods of Sewage Treatment.

Early studies made by this commission indicated that excluding from the harbor as much sewage matter as practicable from those parts of Queens, Richmond, Brooklyn and the Bronx which are tributary to the Upper East river and Upper and Lower New York bays, by the employment of local purification works, the water of the inner harbor would be able to assimilate the sewage from those parts of Manhattan and Brooklyn which were closely built up and where sites could not readily be obtained for the construction of purification works of high efficiency. In this belief plans were begun

for collecting the sewage of the Bronx, Queens and Richmond and gathering it to a number of conveniently located central points for treatment.

Two immediate objects were to be attained by these plans. First, the harbor water in those divisions where the works were located was to be kept clean, and, second, the water was to be protected to such an extent as to insure to the inner harbor the largest assimilative capacity practicable.

As the plans progressed, it became evident that a high degree of purification could not be obtained for as much of the sewage as had been expected. To remove a large proportion of the putrescible material from sewage requires works which could not always be situated where engineering considerations alone would have placed them. In such cases land must be procurable at a price which does not unduly increase the first cost of the project. Of equal importance, it is necessary to locate such works in positions where the odors produced will not injure property to such an extent as to give owners of surrounding land valid claims against the city for damages.

Odors from Efficient Processes.—It is needless to deny that all processes of sewage purification cause smells. The fact should plainly be faced that in the removal the ingredients of sewage which are capable of causing the water into which the sewage is discharged to become offensive, objectionable odors may be produced at the works. The danger of nuisance depends partly upon the degree of thoroughness with which the impurities are removed and partly upon the likelihood that the property holders in the vicinity will find the odors seriously objectionable. There are localities in the City of New York and vicinity where objectionable odors are continually produced by manufacturing establishments with little or no complaint from property holders. But these situations are not usually well placed for sewage disposal plants, and it is doubtful of the city would be justified in adding to these odors even if it became otherwise desirable to construct sewage works there. Manufacturing plants which are objectionable, such as slaughter-houses, bone-boiling establishments and fertilizer factories, usually have to move further and further away, as the cities in which they are located grow. Nuisances of this kind become increasingly objectionable as time proceeds, for more and more people become affected and the public becomes increasingly fastidious.

Such strong and offensive odors as are produced by so-called offen-

sive trades are not likely to be produced by sewage works, but the difference is sometimes not great, and the erroneous belief that sewage odors are in some way connected with disease, if not actually a cause of it, adds greatly to the objectionableness of sewage purification plants in any locality.

33 A convenient and economical location for sewage works is hampered by the uncertainty that they will be permanent. Unlike some manufacturing plants, they cannot well be moved in case they produce a nuisance. If they are objectionable at first, they are likely to become more so with the passage of time. Owing to the protest with which a proposal to build a municipal plant for the thorough treatment of sewage probably would be received in almost any part of New York City, this commission has felt compelled to confine its plans largely to works of the simplest character or carry the sewage to a distant point for disposal. In the selection of sites, considerable difficulty has been experienced because of the changing character of many localities. Few parts of New York are permanently constructed. Solidly built-up sections are constantly changing from residence to business occupancy. Suburban districts are rapidly becoming urban, and rural territory is being converted to suburban uses. Each change increases the value of the land. The most rapid developments, and the most uncertain, are sometimes in the very localities where it would be most convenient to build sewage disposal works. Here unimproved property, even farm land, is not infrequently held at a high valuation in the expectation that a strong demand for real estate may set in at any time.

Owing to the facts here mentioned, this commission has not found it feasible to design works which would purify the sewage tributary from the outlying territory to a high degree, and the water which will reach the inner harbor will consequently not have as great a capacity for assimilating sewage as theoretically it should possess.

What is here said as to the nature of the works which it has been feasible to design for Queens, Richmond and the Bronx applies with greater force to the Lower Hudson, Lower east River and Bay Division. The aggregate volume of sewage produced in this division is now great, and thirty years hence will be about double what it is today. Such treatment as it is practicable to accomplish within the territory where this sewage is produced will remove only a small proportion of the ingredients which are capable of reducing the amount of oxygen in the water into which the effluent is discharged. Sprinkling filters, contact beds, sedimentation basins and chemical precipitation plants, cannot be considered for want of land and because of the odors which such works would produce.

The forms of treatment which could be best employed on the shores of Manhattan and Brooklyn would be such as could be carried on with grit chambers and screens.

34 Grit Chambers and Screens.—In some respects grit chambers and screens are well suited to the conditions. Beside being compact, they produce little odor; they can be located partly below ground; they require no extra pumping; they are comparatively inexpensive to operate; they can be employed without

highly skillful supervision, and it is practicable to have many plants of moderate capacity. Against them is chiefly the criticism that they remove only the largest particles of sewage matter and leave the dissolved organic matter and finely divided putrescible materials to pass to the harbor. Notwithstanding this fact, they would serve usefully in attaining the standard of cleanness which the Metropolitan Sewerage Commission has proposed for the water, particularly as respects requirements Nos 1 and 3 of the standard. This standard follows:*

1. Garbage, offal or solid mater recognizable as of sewage origin shall not be visible in any of the harbor waters.

2. Marked discoloration or turbidity, due to sewage or trade wastes, effervescence, oily sleek, odor or deposits, shall not occur except perhaps in the immediate vicinity of sewer outfalls, and then only to such an extent and in such places as may be permitted by the authority having jurisdiction over the sanitary condition of the harbor.

3. The discharge of sewage shall not materially contribute to the formation of deposits injurious to navigation.

4. Except in the immediate vicinity of docks and piers and sewer outfalls, the dissolved oxygen in the water shall not fall below 3.0 cubic centimeters per litre of water.†

Near docks and piers there should always be sufficient oxygen in the water to prevent nuisance from odors.

5. The quality of the water at points suitable for bathing and oyster culture should conform substantially as to bacterial purity to a drinking water standard. It is not practicable to maintain so high a standard in any part of the harbor north of the Narrows or in the Arthur Kill. In the Lower bay and elsewhere, bathing and the taking of shellfish cannot be considered free from danger of disease within a mile of a sewer outfall.

Inasmuch as grit chambers and screens seem to afford the best practicable means available for treating the sewage of Manhattan and Brooklyn locally, it is desirable to consider in some detail how such works would be constructed, how many plants would be required, about where they should be built, what they might cost and how much improvement they would accomplish. In studying these questions, two chief considerations have appeared to be important. First, the outlets from the works should be so built that the treated sewage will be promptly and thoroughly diffused, and Second, the plants should be so located as to permit the sewage to be collected to them without unnecessary difficulty or expense.

Submerged Outfalls.—Owing to the incompleteness of the purification, and the necessity of complying with requirement No. 2 of the

*Report Metropolitan Sewerage Commission of New York, August, 1912, page 70.

†With 60 per cent. of sea water and 40 per cent. of land water and at the extreme summer temperature of 80 degrees F., 3.0 cubic centimeters of oxygen per litre corresponds to 59 per cent. of saturation.

Standard of Cleanness, it would be necessary to discharge the
 35 effluent from the plants in such a way as to produce the most immediate disappearance of the sewage which is possible. For this purpose, it is desirable that the outfalls should be near or upon the bottom and be so located that ample and strong currents will sweep by them.

The construction and maintenance of outlets at the bottom of the tidal channels some distance from shore would be difficult. The outlets would have to be so built as to meet all the requirements of the United States Government which has supervision over the maintenance of the channels for the purposes of navigation.

Locations for Outlets.—Bearing in mind the difficulties of construction and maintenance, as well as the advantages of carefully selected places, a number of points have been chosen along the shores of Manhattan and Brooklyn where the sewage, after treatment, could with the greatest advantage be discharged.

The facility with which the sewage could be collected to suitable points for treatment was taken carefully into consideration in selecting the points of outfall. It was thought desirable that the sewage should require the least amount of pumping possible; that the plants should not have to be placed too far below tide level and that the greatest possible normal flow of sewage should be gathered to each plant.

Considerable care has been taken in the designs to make an economical use of land, to provide for adequate inspection, and repair, not only of the apparatus, but of the structure itself, to insure light and ventilation and to facilitate the cleaning of the basins and screens and the removal of the impurities from the plant. Numerous forms of grit chambers have been designed and studied. Every form of screen which the experience of other cities had proved reliable and efficient have been considered with the result that the type employed in the new works at Hamburg, Germany, was chosen as the most suitable for these works.

8. Plan for the Disposal of the Sewage of this Division.

Investigation having shown that it will be impossible to discharge all the sewage into the water in the vicinity of the territory where it is produced, even after such purification as is practicable, it becomes necessary to consider where it can be taken and what can be done with it.

Amount of Sewage to be Taken Away.—It will not be worth while to take a small amount of sewage from the inner harbor. To accomplish much benefit, the volume will have to be large both actually and in relation to the total quantity produced in this division.

36 If possible, it should be taken from a part of the harbor which needs relief both on its own account and because of its influence on adjoining sections. As far as practicable, the sewage should be collected from a region of dense population in order that the length of the sewers shall be no greater than necessary. For the

same reason the distance from the central point of collection to the point of disposal should be as short as possible.

This report shows that the greatest burden of pollution which is placed upon any large portion of the harbor is discharged from Manhattan and Brooklyn into the Lower East river. Here within a distance of 4 miles, about 200,000,000 gallons of sewage are discharged every 24 hours from about 50 outlets located along the crowded shores. Not only is the volume of sewage large, but, as shown elsewhere in this report, the waters are peculiarly unsuited to receive it.

If this polluting material can be removed, the waters in the immediate vicinity will be improved and the excessive burden of pollution now put upon the whole inner harbor will be relieved. An improvement of the waters of the Lower East river is desirable for the help it will give in disposing of the sewage which, in accordance with the commission's plans already announced, will be brought to Ward's Island.* At Ward's Island the large quantity of sewage which will be brought from the Harlem river will be passed through settling tanks and discharged into the deep waters of Hell Gate, and reliance must be placed upon the digestive capacity of the waters to oxidize the liquid organic matters.

If 200,000,000 gallons of sewage per day can be kept out of the Lower East river, the ratio of sewage to water in that section will improve sufficiently to meet all requirements of this commission's standard of cleanness for the present. The ratios of water to sewage which will exist in the Lower East river are given in Table XIII.

TABLE XIII.

Ratios of Sewage to Water in the Lower East River, if 200,000,000 Gallons of Sewage per Day Are Kept Out of these Waters.

Year.	Sewage to water at low tide.	Sewage to tidal prism.	Sewage to net ebb flow.
1910.....	1 to 1090	1 to 204	1 to 30
1940.....	1 to 178	1 to 33	1 to 5.6

Direction in which to Take the Sewage.—There are not many directions in which the sewage can be taken. It would be impracticable to carry it north into Westchester County, for the land there lies at too great an elevation. It would be impossible to carry it west because the people of New Jersey would object to receiving it. The idea of discharging it into the Hudson river cannot be entertained, for if this were done that stream would become too heavily polluted. Sentimental considerations require that the Hudson shall not be made a receptacle for the sewage from other parts of the harbor.

It would not be feasible to carry the sewage to Long Island sound;

* Preliminary Report IV. Study of the Collection and Disposal of the Sewage of the Upper East River and Harlem Division, July, 1912.

the distance would be too great, the volume of water there available would be insufficient, the danger of polluting extensive shellfish beds would be large, and the risk of contaminating the shores in the vicinity of villages, towns and country estates too imminent.

The sewage could not be taken east on Long Island, except to a distance of 30 or 40 miles, for its disposal would be certain to produce nuisance and, consequently, serious injury to property already occupied for residence purposes or likely soon to become valuable for this purpose. Furthermore, opportunities for the disposal of the effluent of treatment works are lacking on Long Island, the north shore of which is deeply indented with bays and, for the most part, high and rocky, and the south shore bordered with broad, shallow bays and marshy islands, where the flow of tidal water is relatively slight.

Staten Island Not Suitable for Very Large Sewage Works.—To the southwest of this division lies the Borough of Richmond, or Staten Island, and much sewage could be brought there for treatment as far as engineering considerations are concerned. There are several thousand acres of marshy land on the west side of this island bordering the Arthur Kill which might be employed for sewage disposal, provided no nuisance was produced.

The sewage could be taken to the disposal works by a tunnel which could be driven beneath the waters of Upper New York bay to the north shore of Staten Island, and thence through the high land to the low-lying area near the Arthur Kill. The Arthur Kill has been dredged for the convenience of ships and could receive a well purified effluent, although owing to its small volume of flow and the oscillating effect of the tide, the capacity of the Arthur Kill for unpurified sewage is comparatively small. If the sewage could not be purified sufficiently to discharge the effluent into the Arthur Kill, it would have to be carried by tunnel eastward from the treatment works to the waters of Lower New York bay.

It is probable that treatment works capable of purifying the sewage to such an extent as would permit the effluent to be discharged into the Arthur Kill would be impracticable on Staten Island. Apparently some oxidizing process, either sprinkling filters or possibly contact beds, would have to be employed. It is probable that
38 if either of these processes were used to treat the quantity of sewage which would have to be dealt with, not less than 200,000,000 gallons per 24 hours, with a certainty of more later on, objectionable sanitary conditions would be produced. The sewage would be septic and, consequently, likely to produce odor when brought into contact with the air either in the fine spray necessary in sprinkling filters or in the large areas of surface exposed by the broken stone of contact beds. The likelihood of trouble from flies, a frequent any annoying feature in sewage works, should also be considered. The peculiar mist which sometimes hovers in calm weather over extensive areas of sprinkling filters would prove a source of grave concern to property holders, even at a considerable distance from the works. Before the authorities of the Borough of Richmond would give their consent to receiving the sewage of this division in

that borough for disposal, it is probable that they would insist upon more assurance of immunity from nuisance than safely could be given.

Added to the sanitary difficulties which would attach to the disposal of the sewage by works upon Staten Island is the consideration of cost. It would be expensive to carry the sewage of this division to Staten Island and there dispose of it. The tunnels would be long and, in places, very deep. The foundations for the works on the lowlands in the western part of Staten Island might prove difficult of construction. The outlet tunnel for the effluent would be long and costly.

Objections to Collection at Barren Island.—Two other possible means of disposing of the sewage of this division remain to be considered. First, collection to the vicinity of Barren Island, near the mouth of Jamaica bay, and treatment there, with a discharge of the effluent at sea. Sanitary considerations, such as have been mentioned in connection with the possibility of carrying the sewage to Staten Island, would weigh heavily against purifying the sewage any more completely than is absolutely necessary at this point. The outlet would therefore have to be long enough to carry the sewage far from shore.

Unless the sewage was purified in bacteria beds, it would be necessary to extend the outlet some miles out to sea beyond Rockaway Point in order to make sure that the sewage would not be carried back to the land by the wind and tide, and there are practical difficulties in the way of doing this. The necessary tunnel for this purpose would be very difficult to construct. It would have to be at least 75 feet below the surface of the water, in order to cross well beneath the deep, swiftly-flowing channels of Rockaway inlet. The water at this point is between 30 and 40 feet deep at low tide. Proceeding seaward it would not be found desirable to approach much nearer the surface with it. The point of outfall should probably be located about 2 miles from shore. This would be an unfavorable location for an outlet crib or other permanent structure, for it would be exposed to the full force of the Atlantic ocean and the shifting sands. This project thus has weighty arguments against it.

Advantages of Disposal at Sea.—The sewage from the Lower East river section can be taken directly to the sea, and this is the plan which the commission recommends. In accordance with this plan, central collecting points will be established which will be tributary to a general central station, to which latter point will be gathered such part of the sewage as needs to be carried to a distance. Pumps will be located at the central station and from it a main will run directly to an outfall island to be built about 3 miles from land on a sandy reef. This reef is one of a series of shallow areas, interspersed with channels, which once formed the bar to New York harbor. It lies slightly to the west of an imaginary line between Sandy Hook and Rockaway Point. The outfall will be about 13 miles from the New York City Hall, 6 miles from the Narrows, over 4 miles from Sandy Hook and about 3 miles from Coney Island. The point selected for this island is shown in Plate I, following page 48.

As much sewage as it is necessary to carry to a distance from the Lower East river, Hudson and Bay Division can be taken to the island for disposal. As time proceeds and the quantity of sewage increases, the main sewer can be duplicated and the provisions for treating and discharging the sewage at the island can be enlarged.

A large part of the sewage of this division is now discharged into the waters of the Lower East river. If this sewage is taken away for disposal, it will for some time be possible to discharge the sewage from the rest of the division with no other treatment than screening and passage through grit chambers. The water of the Hudson will be capable of assimilating the sewage produced on the west side of Manhattan Island and the water of the Upper bay could take the sewage produced along the Brooklyn water front from Governors Island southward.

All the sewage from this division, except that part which is taken away, should be passed through grit chambers and screens and, where feasible, the dry weather flow discharged through submerged outlets. In course of time, if the quantity of sewage from this division, as well as from that part of the Upper East river and Harlem Division which would be concentrated at Ward's Island, increases to such an extent as again to place an excessive burden upon the waters of the East river, the sewers can be extended and finally the Ward's Island works can be connected with a main sewer to the artificial island for disposal.

40 The plan of relieving the harbor of its heaviest burden by at once taking to sea a large part of the sewage which flows to the Lower East river and increasing the scope and magnitude of the work as necessity arises, appears to this commission to be a necessary and sufficient solution of the problem. In no other way can the sewage be disposed of with so little chance of danger or offense. The project has the advantages that it will afford, at minimum expense, all the relief that is needed for the present and is capable of expansion in the future.

There are no selfish industries in the vicinity and no currents which would carry any of the sewage to a bathing beach. The sewage will not be exposed long enough to the air to cause annoying odors to be given off and there will be no opportunity for flies to breed.

The plan is in accordance with the best engineering precedent. There is no feature connected with it which is untried or experimental. It avoids offensive, complicated and uncertain processes of purification. It is based upon a careful consideration of the needs of the whole harbor. It leaves the waters of the inner harbor in a sufficiently improved condition for the assimilation of such sewage as cannot be kept out of the waters without wellnigh prohibitive expense.

Ultimate Digestion by the Sea Water.—The project for carrying a part of the sewage to sea contemplates the treatment of the sewage at the island and the ultimate digestion of the liquid organic matter of the sewage by the sea water. Responsibility for the disposal

of the sewage cannot cease until all the ingredients are rendered harmless and inert. It is important that the sewage shall not flow from the outlets as a coherent mass and that none of its elements shall be carried to the inner harbor or find their way, under the influence of wind or tide, to the shore. Accumulations of solid matter injurious to navigation must not be permitted to occur, nor must odors or flies or other objectionable features too commonly associated with sewage disposal works exist to mar the natural attractiveness and healthfulness of that part of the ocean where the outlet is located.

The liquid sewage matters will have a strong avidity for oxygen and will be rendered inert by the oxygen-saturated sea water with which it comes in contact. The great amount of water available at the point of outfall will have an abundant capacity to digest the liquid sewage.

At first the form of treatment needed at the island will be settlement in tanks perhaps aided at times by precipitants. In addition, it may be practicable to disinfect the sewage and produce a considerable amount of oxidation by the addition of bleach or electrolytically produced hypochlorite.

If at any time in the future it becomes desirable to completely purify the sewage, no such favorable location for the necessary works can be found in the metropolitan district than this artificial island. Owing to the shallowness of the water and the ease with which filling can be obtained, land can be made here for less money than an equal area can be bought on shore at any point not more distant from the New York City Hall.

In addition to the sewage from the Lower East river section, it will ultimately be feasible and desirable to send the sewage of the western Jamaica bay sub-division to the island for disposal. This would make it unnecessary to construct treatment works at Barren Island as proposed in an earlier report of this commission*

9.—Collecting the Sewage to the Outlet Island.

Sub-division of the Territory.—The territory included in the Lower Hudson, Lower East River and Bay Division has been separated by this commission into 32 sub-divisions for the purpose of laying out the works which will be necessary for the sanitary disposal of the sewage, and each sub-division has been given a number. The sub-divisions numbered 1 to 12, inclusive, comprise that part of Manhattan which is naturally tributary to the Hudson river. Sub-divisions from 13 to 26 are in Manhattan and Brooklyn, bordering upon the Lower East River. Sub-divisions 27 to 31 are in Brooklyn and border on the Upper bay. Sub-division 32 borders on the Narrows and Gravesend bay.

The sub-divisions vary in size and in quantity of sewage which they produce. The boundaries which have been approximately established are intended to show the limits within which it will be feasible to collect the sewage to a central point on the water front in each

*See Preliminary Report III.

sub-division. The central points are usually near existing large sewers and, as often as practicable, at places which are favorable for a prompt admixture of the sewage effluent with the harbor water.

As stated elsewhere in this report, the dry-weather flow of sewage, after collection to a central point in most of the sub-divisions, should be passed through grit chambers and screens and so discharged into the water as to insure prompt diffusion.

The dry-weather flow of sewage produced in the six following sub-divisions bordering upon the Lower East river should not be discharged into the neighboring waters, but should be gathered to a central point and thence carried to sea: In Manhattan, 13, 14 and 15, and in Brooklyn, 24, 25 and 26.

The method of collection in these subdivisions from which the sewage is to be carried to a distance may or may not be the same as in those sub-divisions from which the sewage will be discharged into the neighboring waters. There are various ways in which the sewage can be collected. One method may be described by way of illustration.

The dry-weather sewage can be collected by marginal sewers to a central point in each sub-division and there passed through grit chambers and screens. Passing beneath each central collecting point will be a deep-lying intercepting sewer which will receive the sewage after it passes through the screens and grit chambers. Storm water in excess of twice the dry-weather flow will pass by overflows at each outlet directly to the river. Further details of this plan follow.

The Necessary Marginal Sewers and Interceptors.—Each central collecting point will have storm overflows, regulators and tide gates so arranged as to discharge directly into the neighboring waters the excess flow of sewage during periods of rainfall. The interceptors are intended to be large enough to accommodate twice the mean rate of flow during periods of dry weather. The maximum rate of dry weather flow is assumed to be about one and one-half the average rate per 24 hours. This will permit the interceptor to carry off some of the first flush of storm water even if it reaches the plant during the hour of maximum sewage production.

The marginal sewers required to collect the sewage from the present sewers to the central points in each sub-division will lie as close to the surface of the ground as physical conditions permit.

The interceptors will be situated at a considerable depth and be so located as to avoid as far as possible difficulties of construction. It will probably be necessary to construct the interceptors by shield tunneling. In making the plans and estimates, careful attention has been given to the information available concerning the geology of the territory passed through as determined by borings made by the Public Service Commission, Board of Water Supply and others.

The Manhattan Lower East Side Sub-divisions.—The interceptor from sub-division 13 will run from a screening plant situated near Roosevelt St. parallel to the shore to Corlears Hook, where the sewage will empty into a siphon and be carried to Brooklyn. This South Manhattan interceptor will be 5' 9" in diameter.

A second interceptor, which may be termed the North Manhattan

interceptor, will run from East 14th St. southerly to a siphon to Brooklyn which begins at Corlears Hook. The size of the North Manhattan interceptor will be 9' 6" from the screening plant for subdivision 15 to the screening plant for sub-division 14 at De Lancey Slip, where it will increase to 10' 10" in diameter before joining the siphon. The North Manhattan interceptor will be large enough to permit an extension to be made in it, so as to take in the sewage of sub-divisions 16, 17 and 18 in course of time. Profiles of the Manhattan marginal sewers and interceptors are shown on Plate II, following page 48.

The total quantity of sewage to be taken from sub-divisions 13, 14 and 15 is estimated at 99,000,000 gallons per 24 hours in the year 1915. The estimated population for the same year is 680,500, and the area from which the dry-weather flow will be taken is 1,737 acres.

The Siphon from Manhattan to Brooklyn.—A siphon will be required to carry the sewage from Manhattan to Brooklyn beneath the lower East river. The point selected for the crossing is at a narrow part of the river where solid rock may be anticipated. The siphon which will be required to take the sewage produced in 1915 should have a diameter of 8' 9". The depth will be 110 feet beneath the surface of mean low water. The siphon will be 2,300 feet long and extend from Corlears Hook to South 8th St. When the North Manhattan interceptor is extended so as to take the sewage from sub-divisions 16, 17 and 18, it will be necessary to build a second siphon. This can be laid parallel to the first. It is desirable that the siphons needed at first shall not be too large, in order that the velocity of flow may be sufficient to prevent deposits taking place. The velocities considered suitable for the first siphon range between 2 and 5 feet per second.

The Brooklyn North Western Sub-divisions.—That part of Brooklyn which will be tributary to the main sewer to the sea will be treated in a way similar to that described for collecting the sewage from the lower east side of Manhattan. The quantity of sewage to be taken from this part of Brooklyn will be a little larger than the quantity from Manhattan, or about 104,000,000 gallons per 24 hours in 1915. The estimated population tributary in Brooklyn will be slightly larger, or 732,313, and the net area more than three times as large, or 5,790 acres.

The siphons from Manhattan will empty into an interceptor on the Brooklyn shore which will run from a central collecting point at South 5th St. for sub-division 24 to a general pumping station at Wallabout St., near the head of Wallabout canal. This interceptor will be 5' 3" in diameter before meeting the siphon and 10' 3" from the junction with the siphon to the pumping station. This may be termed the North Brooklyn interceptor. In course of time, if it becomes necessary to bring the sewage of sub-divisions 19, 20, 21, 22 and 23 to the general pumping station, this can be done by running another interceptor to the central collecting points in those sub-divisions. It appears to be unnecessary to make further provision for the future at the present time.

44 From sub-division 26 in Brooklyn, which is opposite the lower end of Manhattan, an interceptor should be built to the general pumping station. The central collecting point in sub-division 26 will be near Adams Street and the interceptor leading therefrom should be 4' in diameter. This is estimated to be of sufficient size to take the flow from sub-division 27 in the future. At Hudson Street, this interceptor would receive the sewage collected from sub-division 25. Running around the Brooklyn Navy Yard, this South Brooklyn interceptor should have a diameter of 9' 6" to the general pumping station. Profiles of the Brooklyn marginal sewers and interceptors are shown on Plate III, following page 48.

The General Pumping Station.—The sewage collected at the general pumping station, amounting to about 200,000,000 gallons a day, will have been passed through grit chambers and screens and will be in reasonably fresh condition. It will all flow to this point by gravity. The pumps will be required to raise the sewage from an elevation of about 27 below mean tide and pump it under a head of about 45 feet to the artificial island at sea. The distance to be pumped will be about 11.8 miles and the head to be overcome will be that which is necessary in order to raise the sewage from the level at which it is delivered to the pumps to the level of the tanks where it is to be treated on the island, plus the head required to overcome the frictional resistance offered to the passage of the sewage through the long main. The pumps can be operated by steam, oil or by purchased electric current. It would seem feasible and desirable to drive the pumps with electric power to be obtained from burning the solid refuse of the city in destructors, as is commonly done in England and in certain large cities of Europe.

The Sewage Main to Sea.—The force main through which the sewage will be pumped to the island will be built, for the most part, in tunnel. There will be three shafts, so situated as to permit the work of construction being pushed with expedition and economy. The internal diameter of the completed main will be 12' 10" from the pumps to a point near Sheephead bay, where it will be increased to 14' in order to accommodate the sewage from the western part of the Jamaica Bay Division. A profile of the outfall main is shown on Plate IV, following page 48.

The estimates given below are based upon the work already outlined, but since the sewage main will pass comparatively near Jamaica bay, it may be desirable to modify the plan which this commission proposed for the Jamaica Bay Division* to such an extent as to permit the main to take to the island the sewage which it has

45 been proposed to collect from Brooklyn to Barren Island for treatment and disposal. The advantages to be gained by this change are (a) reduction in cost over the Barren Island project and (b) avoidance of the necessity of constructing a sewage disposal plant at the entrance of Jamaica bay. By adding the sewage of the western Jamaica bay sub-division to the sewage of Manhattan and Brooklyn which is pumped to the island, the disposal works will

* Preliminary Report III, November, 1911.

be centralized and questions of administration and maintenance will be simplified.

The Western Jamaica Bay Sub-division.—The sewage from the western part of the Jamaica Bay Division will be collected at two central pumping stations, one at Hendrix Street and the other at Flatlands Avenue. From the eastern pumping station, an interceptor 9' to 9' 6" in diameter will extend for 2.6 miles to a second pumping station at Flatlands Avenue. From this point the interceptor, enlarged to 11' 4" in diameter, then 11' 8" and finally to 12' in diameter will extend to Nostrand, where it will be joined by a small interceptor of 27 inches from the present sewage disposal works for Sheephead bay which will be converted into a pumping station. The interceptor enlarged to 12' 4" will end at a pumping station to be located at Ocean Parkway and Avenue W. This last pumping station will discharge the sewage into the main which runs to the island.

A pumping station to be located at 86th Street and Avenue V in Bensonhurst will discharge through a 4' interceptor to the pumping station which will serve the western part of the Jamaica Bay Division. The sewage of Coney Island will be pumped from the present plant known as Caisson No. 3 directly to the main sewer.

The quantity of sewage from the western part of Jamaica bay will be about 47,000,000 gallons per day in 1915. The population will be about 343,000 and the area served 19,000 acres.

The Artificial Island.—The tunnel to the island will be 14' in diameter and constructed at a depth of about 60 feet, the material to be penetrated being sand. It will be possible to construct the tunnel with two headings, one from the shore and one from the island, the two meeting and being properly joined.

The point selected for the island has been carefully chosen with reference to economy of construction, resistance to the destructive influences of tidal currents and storms, freedom of obstruction to the free flow of tidal water in and out of the harbor and absence of sanitary objections.

The location lies to the north of Sandy Hook and to the south of Coney Island. Its position is latitude 40 degrees 31½ minutes and longitude 73 degrees 58½ minutes. The water within a mile from the island in all directions varies between 7 and 40 feet in depth, the average being about 20 feet at mean low tide.

46 The plan of the island is approximately rectangular, the seaward side being rounded. The area at the start will be about 20 acres. This can be extended as required. The general plan of the island is shown on Plate V, following page 48.

The outer face of the island will be a wall of rip rap composed of large pieces of broken stone carried to the site on bents and laid upon the hard sandy bottom. It is expected that some settlement will occur, due to the water cutting sand away from under the stone. When sufficient rip rap has been placed to stop this action of the water, no more settlement is to be expected. The main bulk of the island will be composed of sand supplied from a suction dredge, which will take its supply from the bottom of the sea in the vicinity.

The height of the island above mean low water will be about 18 feet. The length will be 1,300 feet and the width 1,000 feet. The side of the rip rap wall which is exposed to the sea will have a slope of 1 vertical upon 3 horizontal and the other sides will have a slope of about 1 on 2. The cost of constructing the island has been estimated at about \$615,000.

The landward side of the island will be provided with a quay wall for the accommodation of vessels engaged in taking supplies and other materials to and from the island. Shelter from the sea will be provided by a breakwater, which will enclose a small harbor.

The island will contain a plant of settling tanks in which the sewage will have an opportunity to deposit its solid matters during a period of about two hours. These tanks will be of modified Dortmund tank construction, similar to those recently constructed at Toronto, Canada. Provision will be made for treating the sewage if necessary with a coagulant before passing it into the tanks.

After treatment, the sewage will be discharged through a number of outlets arranged radially on the seaward side of the island. If desirable, it will be feasible to pump sea water into the sewage and provide for the mixture of the two before the discharge takes place. Such admixture would facilitate the immediate diffusion of the sewage in the sea water, but the active agitation and free movement of the great volume of water in the vicinity of the island will probably make the preliminary admixture of sea water and sewage by pumping unnecessary.

The material which settle out in the tanks will be carried to sea in boats and dumped.

Cost.—This project will require the construction of about 5.3 miles of marginal sewers in Manhattan and Brooklyn and about an equal length of interceptors in these two boroughs. The siphon from Manhattan to Brooklyn will be a little less than a half mile long. The main from the pumping station to the island 47 & 48 will be about 13 miles long. If the Jamaica bay sewage is brought to the island, about 2 miles of collectors and 7 miles of interceptors will be required in addition.

The studies which have been made indicate that the total cost of construction would be about \$22,874,000, including \$4,072,000 for the Jamaica Bay Division. The fixed charges, including sinking fund and interest, would be about \$1,157,000, allowing \$206,000 for the Jamaica Bay Division. The total maintenance and fixed charges would amount to about \$1,803,000, including \$286,000 chargeable to the Jamaica Bay Division.

METROPOLITAN SEWERAGE COM-
MISSION.

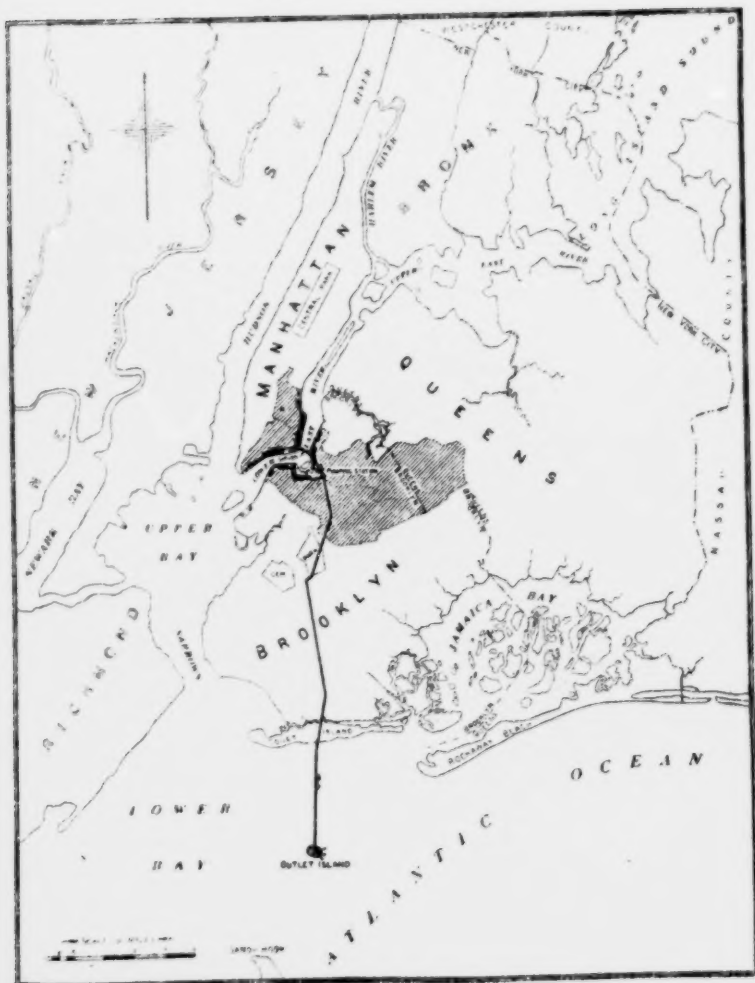
GEORGE A. SOPER,
JAMES H. FUERTES,
H. DE B. PARSONS,
CHARLES SOOYSMITH,
LINSLEY R. WILLIAMS.

February, 1913.

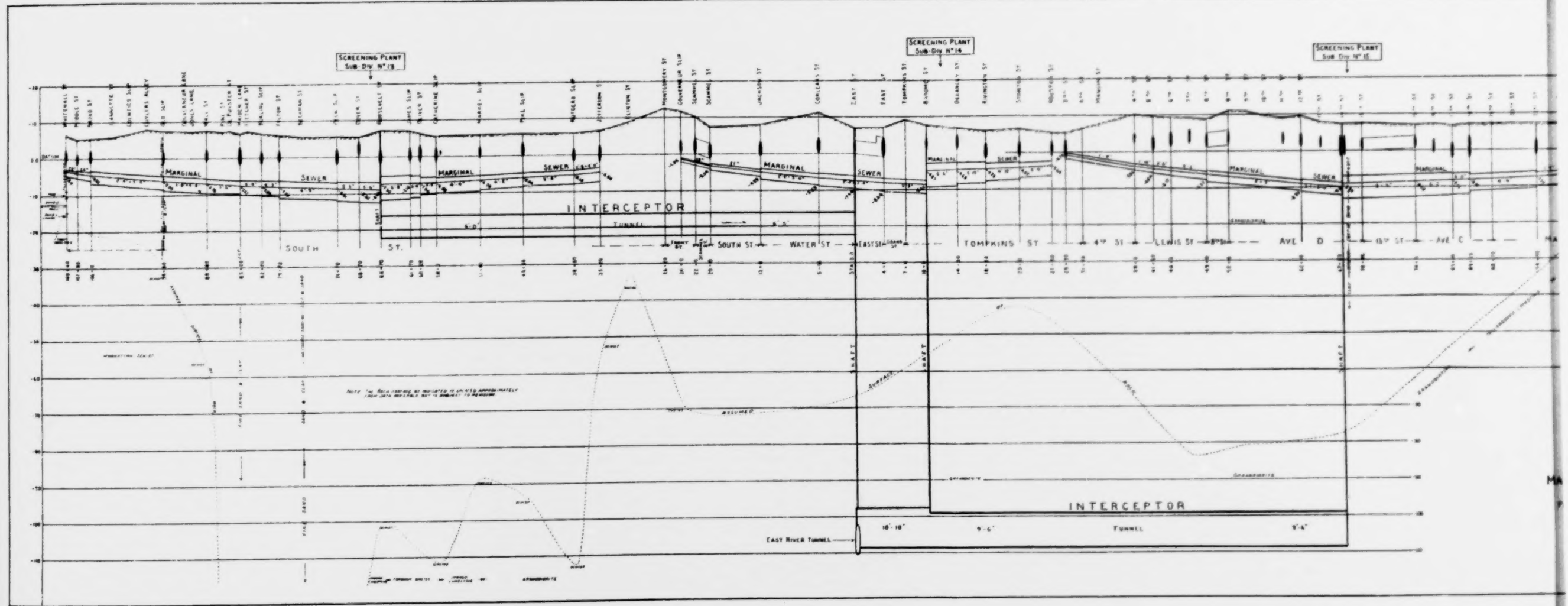
(Here follow plates marked I, II, III, IV, and V, Exhibit No. 202.)

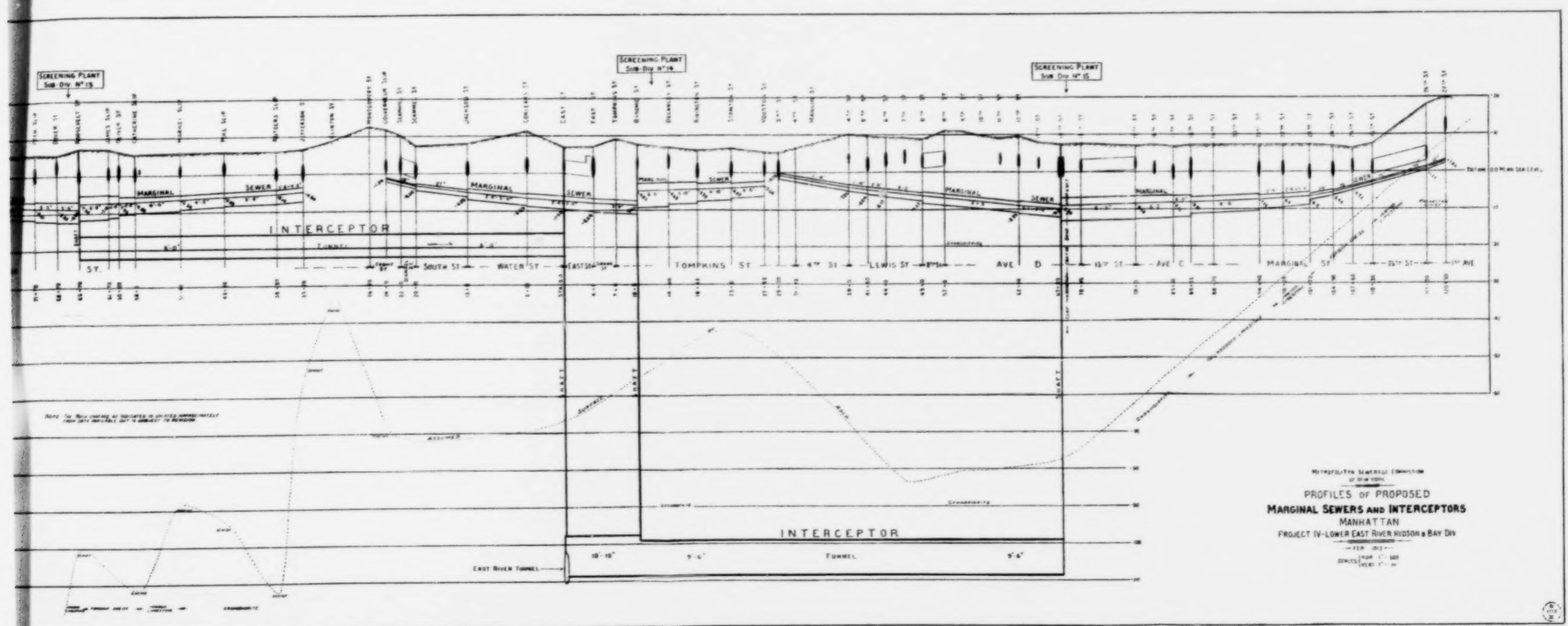
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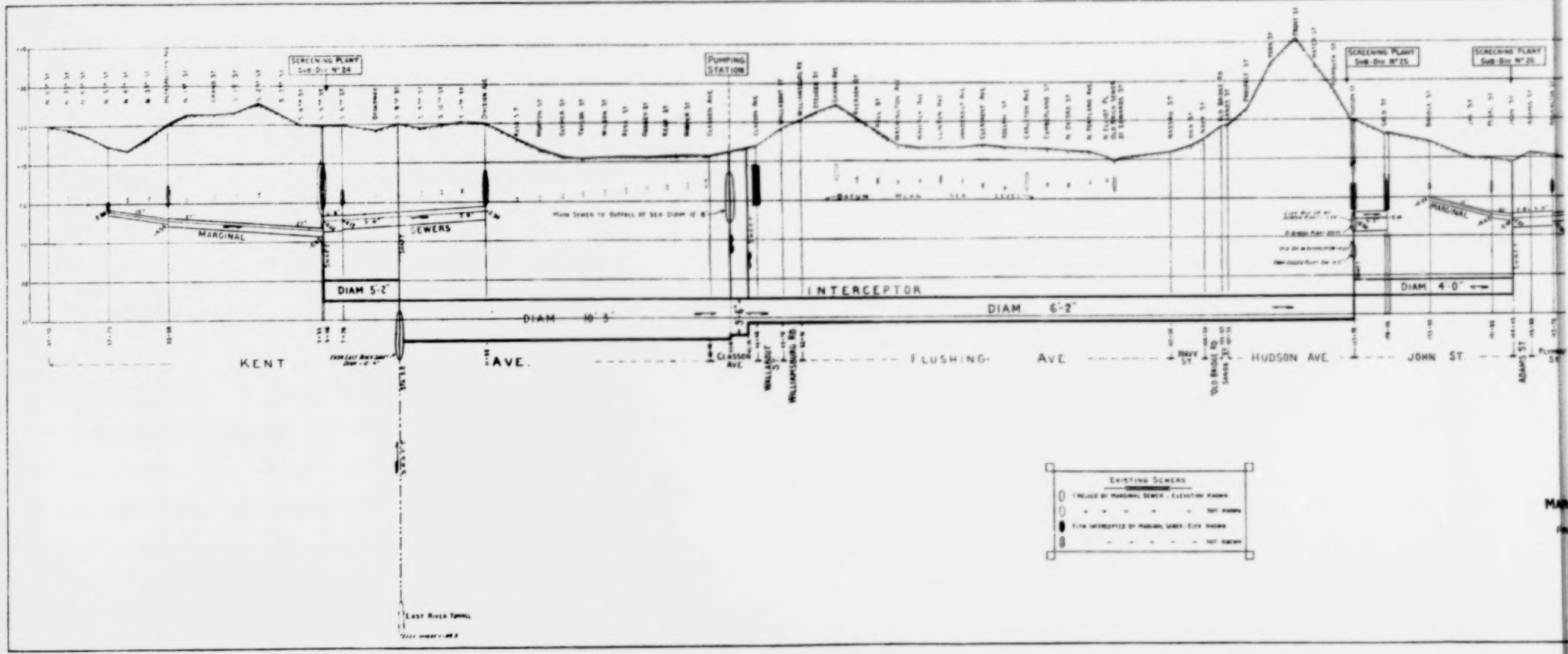
PLATE I



PROJECT FOR THE RELIEF OF THE LOWER EAST RIVER
AGAINST EXCESSIVE POLLUTION







MAP

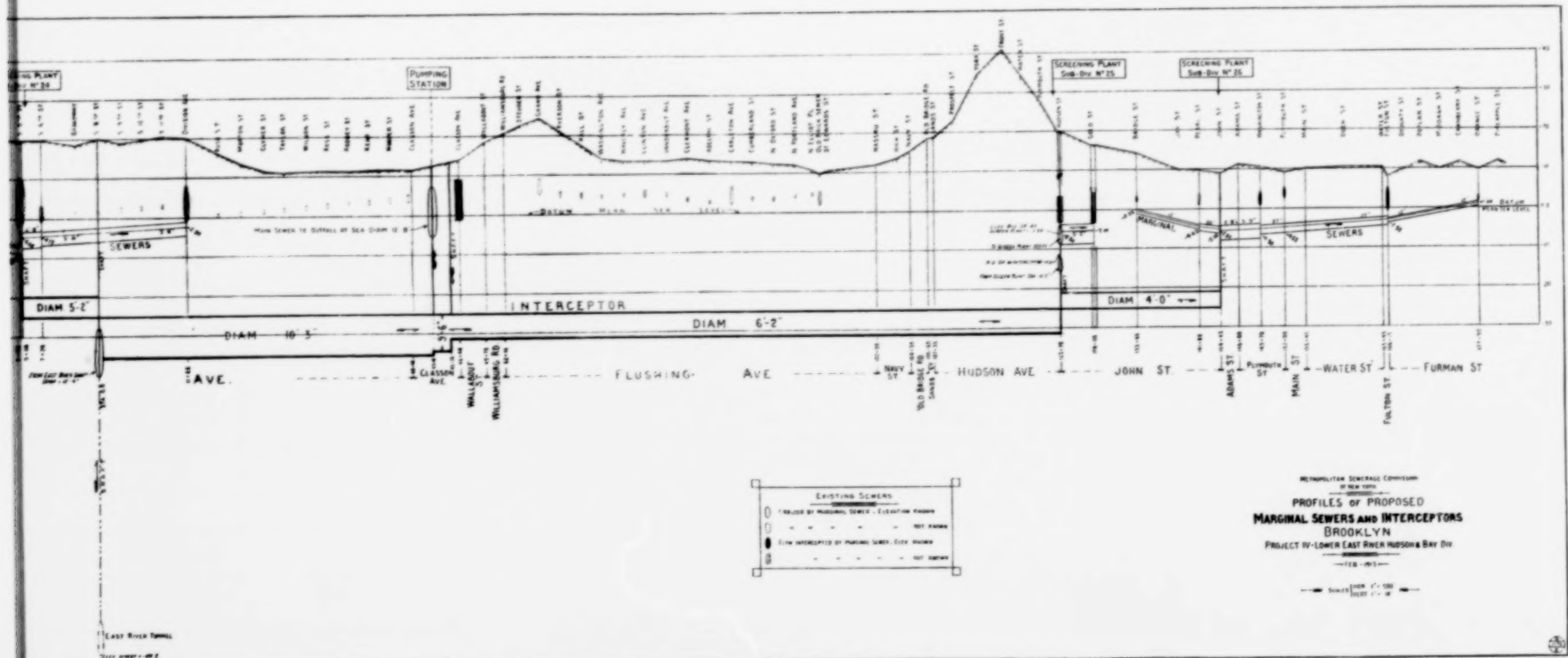
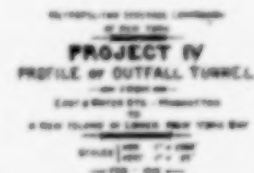


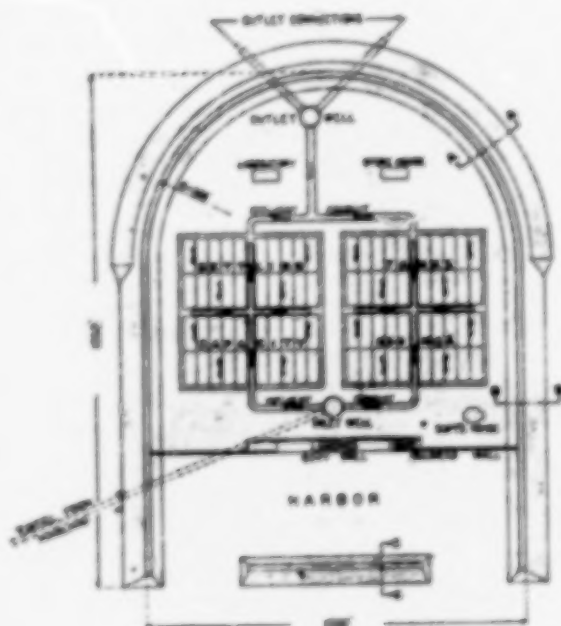
PLATE 20



48° Ec 202

(Exhibit No 202)

PLATE V



REPUBLICAN ENGINEERING CORPORATION
OF NEW YORK

PLAN OF PROPOSED
OUTLET ISLAND

Scale of Feet
0 10 20 30 40 50 60 70 80 90 100

Appendices.

I.

Studies for Grit Chambers, Screens, and Regulators.

The grit and screen chambers could be constructed, beneath the level of the street pavements, but in all cases it would be desirable, and in some instances probably necessary, to provide a super-structure. All the plants would be small and where a building over them was necessary, it could be made architecturally unobtrusive in appearance. If the sewage were collected by a combined system of sewage, the plant would require to be provided with means for separating a part of the storm water and the latter could discharge directly to the water. It would be feasible to pass three times the dry weather flow of sewage through the plant during periods of storm, and if this were done the work of the water from the streets would be provided for in the works. A study for a grit chamber is shown in Plate VI, following page 52.

In addition to the provisions for avoiding an excess of storm water, the principal features of the plants would be a grit chamber and screens, pumps, tide gates and submerged outfalls. The grit chamber would be essentially an enlargement of the sewer and be of such design as to provide for the slowing of the sewage flow as much as practicable. A prominent feature should be the means for cleaning out the grit and other solid matters which would be deposited. Elaborate methods for cleaning grit chambers are employed in some European sewage disposal works, but simple and effective dredging apparatus appears to be preferable. The material dredged from the grit chamber should be dumped into suitable carriers. These carriers, which could also carry away the screenings would operate electrically. They should convey the materials to some dock or pier where a vessel could carry the impurities to sea or the inflammable part of the refuse could be disposed of by burning.

On passing from the grit chamber the sewage should be screened. After considering many types of screens employed in Europe and America, including those capable of removing the utmost quantity of suspended matter possible, it seems best to employ a moving bar screen with openings of about $4/10$ of an inch. The type used in the new installation at Hamburg, Germany, appears to be suitable for New York. This screen consists of an endless belt of bars arranged at an inclination to the flow of the sewage. The sewage passes between the bars and leaves the solids, which are caught and carried upward on the screen belt as it slowly revolves. The screens which are carried up out of the sewage are removed from the belt by means of brushes and a hose and discharged upon a belt conveyor

50 which carries the material to a car which stands in readiness. The size of the openings between the bars of this screen do not necessarily indicate the size of the particles removed from the sewage. If the screen is revolved very slowly, its effectiveness in re-

moving suspended matter will be increased. After the sewage leaves the screens, it passes to the pumps. The pumps should be of the centrifugal type directly connected to motors. The pumping equipment should be in duplicate, as should the screens and grit chambers.

Leaving the plant, the sewage should flow under slight pressure to the outer ends of piers, where it would pass downward through a pipe to the bottom and thence outward into the current for discharge. The tide gates should be located near the point where the sewage is passed through the grit chambers and screens.

In order to consider the practicability of installing grit chambers and screens, locations have been tentatively chosen for the outlets and the approximate locations of the works fixed. The next step was to separate the division into subdivisions and select a few of those for more detailed study. The collecting system in each subdivision was assumed to be already complete save for such interceptors and other large sewers as might be needed to gather the sewage which was now passing to the harbor through many outlets to the central plants. Four sub-divisions were selected for special study, in which the topography and other conditions were dissimilar.

Sub-division No. 5.—One of the sub-divisions was on the Hudson river shore of Manhattan Island, between the northern end of Central Park and the Riverside Park. The sewage from this area is produced by a high-class apartment house population. The topography is such that no difficulties to drainage exist. The site for the plant was in Riverside Park at 96th Street. The quantity of sewage was 25.4 million gallons per 24 hours during dry weather and three times this quantity was provided for at the plant. The storm water outlets were intended to be carried to the end of the West 97th Street pier and were given a capacity of 270 million gallons per day. The cost, including excavation, sub-structure, super-structure and 15% for contingencies, was \$89,000 for the plant. The outlets for the dry weather flow would run to a point 300 feet off the pierhead and would cost about \$24,200. The outlets for the storm water overflow at the pierhead would cost about \$37,000. Total, \$150,200. This estimate does not include the cost of intercepting the sewage and delivering it to the treatment plant.

Sub-division No. 14.—The second sub-division studied would have a treatment plant at Broome Slip, near the East river. In this case the area drained is occupied by a crowded tenement house population. There would be difficulty in collecting the sewage to the plant, since the ground is, for the most part, low. The works would have a total capacity of 93 million gallons, which would be about three times the dry weather flow. Storm water in excess of this quantity would be diverted directly to the East river, and the rest raised by pumping. In all other essentials the plant would be similar to that at 96th Street. The estimated cost, including excavation, sub-structure, super-structure, machinery and 15% for contingencies, is \$133,000. This figure does not include the cost of collecting the sewage and delivering it to the plant or of conveying it from the works to the outlets.

Sub-division No. 19.—A third sub-division studied contemplates the location of a plant at Orchard Street, Astoria. In this case the capacity would be 87 million gallons per day or three times the dry weather flow. Difficulties of drainage due to low-lying land would require pumps to lift the low level sewage to the works. The estimated cost for excavation, sub-structure, super-structure, machinery and contingencies would be \$81,700, exclusive of the cost of delivering the sewage to the plant or conveying it thence to the outlet.

Sub-division No. 30.—A fourth location for a grit chamber and screening plant would be at the foot of 64th Street, Brooklyn. The capacity in this case would be 68 million gallons per day or three times the dry weather flow. The cost, including excavation, sub-structure, super-structure, machinery, connection with sewer and 15% for contingencies, would be \$147,000, exclusive of cost of conveying the sewage from the plant to the outlet.

If there was one grit-chamber-and-screening plant, in each sub-division, the total number would be thirty-one. If their cost is indicated by the studies made for the four sub-divisions mentioned, the total outlay for them would be in the neighborhood of \$710,000. This would exclude land and the outfalls.

Heavy Rainfalls.—Inasmuch as the frequency with which the storm overflows would come into play should be considered, studies have been made of the records of precipitation as kept by the United States Weather Bureau. The maximum precipitation in each month for 5, 10 and 60 minute periods from April 1, 1896 to January 1, 1912, and for 15, 30 and 120 minute periods from January 1, 1903, to January 1, 1912, have been examined. The results for the months of December, 1896, January, 1897, and February, 1898, are missing. The tabulations of the Weather Bureau were for the most severe single storm each month and it is possible that the actual frequency would slightly exceed that indicated by these diagrams. But the difference would not be so great as to be of consequence in any provision for storm water overflows.

On applying the results of these studies of rainfall, it appears that a volume of storm water in excess of three times the dry weather flow would occur on an average once in about 3½ months and six times the dry weather flow would be received about once in ten months. Ten times the dry weather flow would happen about once in three and one-half years, and the maximum flow for which the plant would be designed, above which the sewer would be surcharged, would occur about once in 6½ years.

Annual Costs.—The annual costs of operating the grit chamber and screening plants have been approximately estimated. These charges do not include fixed charges required on account of intercepting the dry-weather flow nor do they cover the provision of storm water overflows or submerged outlets. The solid matter removed by the basins and screens would be carried, according to these estimates, to the nearest public dump: from the two Manhattan plants by motor trucks serving about four plants each; from the Astoria plant, by chutes to a steamer; from the 64th Street, Brooklyn, plant, it would be conveyed for a short distance to the water

front. In each case, it would be taken to sea by a steamer for disposal. Still better, the screenings could be burned.

The amount of sludge produced has been assumed to be one ton per million gallons of sewage. These estimates are based on the assumption that a sufficient number of plants are in operation to warrant the use of a sludge steamer without which the sea discharges per ton would be much greater than the amount here indicated.

Estimates of Annual Expense of Grit Chamber and Screening Plants.

	W. 96th St., Manhattan.	Broome Slip, Manhattan.	Orchard St., Astoria.	64th St., Brooklyn.
Dry-weather flow, mil- lion gallons per day	30	33	30	50
Operation	\$6,600	\$8,100	\$7,380	\$8,100
Salaries	2,640	29,000*	9,420†	3,100
Power, light and supplies	9,300	37,100	16,800	11,200
Fixed Charges.....	4,500	6,730	4,134	7,438
Total	\$13,800	\$43,830	\$20,934	\$18,638
Per Mgd.....	460	1,328	698	373
Sludge Disposal.....	1,825	1,848	547	1,825
Land charges.....	1,645	1,807	1,643	2,737
Sea charges	\$3,470	\$3,655	\$2,190	\$4,562
Per Mgd.....	116	111	73	91
Grand Total.....	\$17,270	\$47,485	\$23,124	\$23,200
Per Mgd.....	576	1,439	771	464

* Including pumping.

† Pumping 8.9 million gallons per 24 hours.

(Here follows Plate VI, Exhibit No. 202.)

Studies for Tide Gates.

Most of the grit chambers and screens would be situated so close to the tidal level that the plants would be in danger of flooding through the outlet pipes if provision was not made to prevent it. To prevent flooding, tide gates would be needed and these should be of the most reliable form procurable.

Many forms of tide gates have been considered by the Commission, the experience of engineers in America and England being taken carefully into account, and special attention being paid to the best current practice in this direction in Holland. As a result, it is believed that although tide gates are not always reliable, a form can be designed which will satisfactorily answer the requirements of the situation.

Tide gates in common use are of three general types: flap valves, swinging gates and sluice gates.

Flap Valves.—Flap valves which swing on a horizontal hinge are most often used on sewer outlets of moderate or small size, although good examples of this type exist in some large sewers. At Washington, D. C., gates are used which are made of Georgia pine 5 feet 6 inches wide by 8 feet high and at Philadelphia there are gates of yellow pine 18 feet wide and 2 feet high. With large sizes, two flap valves are usually placed in the gate, one above the other, as at Aberdeen, Scotland, and Atlantic City. At Aberdeen, the balanced flaps are of cast iron and the opening for discharge is 5 feet 6 inches by 6 feet 6 inches.

For the flaps to work freely, they should hang loosely from links, as at Atlantic City, or from easy-working hinges. Composition bearings are desirable in order to avoid corrosion. At Washington the hinges and bolts are of bronze. A ring of rubber set into the gate forms a watertight joint, with a cement seat. At Philadelphia, a rubber gasket is provided which bears against a copper seat. To aid in securing a tight closing of the valve, the seat is usually inclined to the vertical; 1 in 6 at Washington, and 30° at Philadelphia.

If the sewer is of large size, the weight of the flap gate may be so great as to interfere with the free discharge of the sewage. Gates which swing on a vertical axis have an advantage over flap valves in this respect. The leaves of such gates are usually made of wood, white pine being used in some cases, as in Boston. To insure tight closing, a counterweight may be hung on a chain passing from a rod projecting from the outer end of the gate to a point above the hinges. In a patented device used in Boston, the hinges are slightly inclined

so as to offset in part the buoyancy of the gates which tends to keep them open. To further insure tightness in the Boston gates, a lead weight which is moved by gravity in a closed sheath attached to one leaf of the gate is hung on a chain which passes over a pulley and then horizontally to a post on the other leaf. The counterweight is thus kept out of the sewage. A rubber strip is attached to the bevel end of one leaf and to each leaf is at-

tached a rubber strip opposite the seat to insure tight closing. A study for a flap tide gate is shown in Plate VII, following page 54.

Sluice Gates.—Sluice gates, or penstock gates as they are often called in Europe, are sometimes employed to more certainly secure protection from back water. In some instances, as at Kings Lynn, a sluice gate is placed behind a flap valve for the added security which is thus afforded. Sluice gates for this use are generally of cast iron and are raised by a screw. As the weight is considerable, a counterweight is often provided, as in the case of a flushing gate in Boston. If the gate is double, it will facilitate opening, the lower half being raised first. An added advantage in having double gates lies in the saving which they afford in head room in case the lower gate is of large size.

Large sluice gates should be mechanically operated, as at Portsmouth, where turbines actuated by the sewage are used to operate twelve 3 foot by 3 foot 9 inch gates. Auxiliary inlets to the turbines are there first opened by hand, although it would seem possible that the operation could be entirely automatic.

At Aberdeen there are two penstock gates, one closing against the tide and one against the sewage, with a flap valve between. They are about 6 feet 6 inches square, with gun metal facings. Each is operated by a 30-inch hydraulic cylinder using water pressure of 35 pounds per square inch.

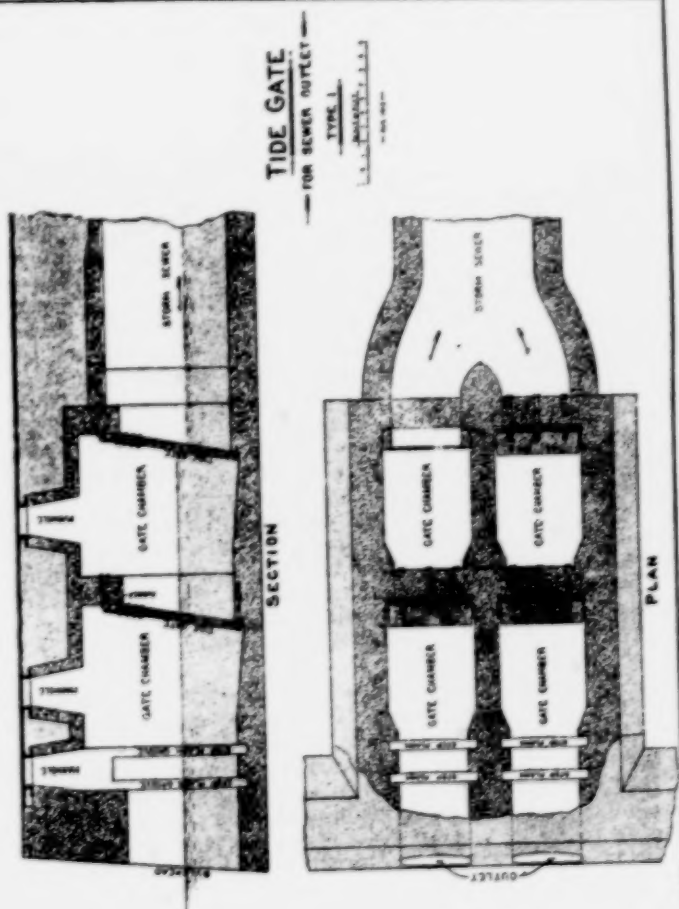
If properly designed and regularly inspected, flap valves are an efficient means of excluding tide water from sewers, but there is always some chance that wood and other floating substances may become caught in the opening and prevent the flap from closing tightly. The Washington gates afford an excellent example of the reliability and economy of this type of tide gate. Sixteen of these gates have now been in service seven years without any expenditure for repairs.

For very large sewers, swinging gates are to be preferred to any other means of excluding tide water. Sluice gates are more certain than flap valves and swinging gates to close tightly, but they are costly and cumbersome, both to construct and operate. Where the tidal ranges are great, they have advantages over other forms on account of their strength and compactness. In all cases tide gates should be built in duplicate.

(Here follows Plate VII, Exhibit No. 202.)

(Exhibit No 202)

PLATE VII



III.

Studies for Submerged Outfalls.

The value of submerged outfalls lies in the fact that they materially aid in bringing about a prompt and thorough mixture of the sewage and water into which the sewage is discharged.

Preliminary to describing a form of construction which appears to be practicable for submerged outlets in the sub-division with which this report deals, it is desirable to consider the circumstances under which sewage will and will not mingle with the surrounding water.

Dispersion and Diffusion.—The terms dispersion and diffusion are sometimes used interchangeably in describing the intermixture of sewage and water, although, strictly, there is a difference in their meaning. The term dispersion implies a separation and scattering, particularly of solid particles, while diffusion refers especially to that form of rapid and intimate mixture which is most often considered as taking place among gases. Both dispersion and diffusion are necessary for the disappearance of sewage. The solids must become scattered and the liquids must become diffused. When solids accumulate, they may form deposits or else masses which are visible at the surface. Unless the liquids become diffused, they do not come into contact with the oxygen which is necessary for their mineralization. When dispersion and diffusion are satisfactory, the discharge of sewage into a large body of water is scarcely, if at all, detectable to the sight.

It is sometimes erroneously assumed that diffusion is everywhere and at all times proceeding rapidly among the liquid particles naturally present in large bodies of water, particularly in such bodies as move under tidal influences, and that to cause sewage to be carried away, it is only necessary to discharge it in not too great quantity. This is a mistake. Some bodies of water should never receive any sewage.

A prompt and general intermixture of sewage and water is often difficult or impossible to accomplish. It is most difficult when the water into which it is emptied has no current or when the current is so slow that there are no eddies or counter currents produced. The eddies and counter currents are necessary for rapid diffusion. It is not enough that the water into which the sewage is discharged should be great in volume, nor that the water should be flowing by a point of discharge at a great velocity. If the velocity is uniform throughout, dispersion and diffusion will not be as satisfactory as it would be if cross currents and eddies existed in it.

56 **Ascent of Sewage in Sea Water.**—Diffusion between sewage and sea water is more difficult than between sewage and land water by reason of the greater specific gravity of sea water. Each cubic foot of sewage is $1\frac{3}{4}$ pounds lighter than an equal volume of sea water and, in consequence of this fact, every foot which is discharged beneath the surface may be considered to be urged upward

with a force of about $1\frac{3}{4}$ pounds. This upward force diminishes as the sewage becomes mixed with the water and is initially less if the harbor water is not as salt as the sea. From the mathematical equation $V^2=2gh$, it is evident that the rate of ascent will vary as the square of the difference in specific gravity, and that the velocity of ascent will be doubled when the buoying force is multiplied four times.

It is, unfortunately, impossible accurately to determine the velocity of ascent of a stream of sewage by means of this or any other formula, but the facts stated are of practical use in considering the best means of causing a prompt and intimate mixture of the sewage and tidal water to take place.

Many experiments have been made by the Metropolitan Sewerage Commission to obtain information concerning the circumstances under which sewage could and could not be made to diffuse in the water of New York harbor. These experiments were carried on in the laboratory, in large aquarium tanks and in the harbor itself. In the latter case, hogheads and tank steamers loaded with sewage were taken to various parts of the harbor and, after being strongly colored with dye, discharged beneath the surface, and the resulting phenomena noted. In these experiments the harbor water varied in salinity. It usually contained about 75 per cent. of sea water. The current into which the sewage was discharged varied from a little less than 1 foot per second to 3 feet per second. Most of the large scale experiments were carried on near the center of Upper New York bay. Further details of this work are described in the report of the Commission of April, 1910, pages 184-215, but the following facts and opinions derived from these studies are of interest here. When sewage is discharged into sea water, the sewage will rise to the top in a mass unless it is intermixed through the mechanical action of eddies and cross currents. Tending to carry the sewage to the top are gas, grease and light solid particles. The sewage is usually warmer than the water into which it is discharged and this difference in temperature tends to carry the sewage upward.

When sewage is discharged into a mixture of 85 per cent. of land water and 15 per cent. of sea water, it appears to be practically in equilibrium, that is, it neither rises nor falls through the water into which it is discharged.

When sewage is allowed to stand at the top of a perfectly quiet body of water, diffusion occurs at once if the water is land water, but not until 48 hours, if the water is a mixture of equal parts of land water and sea water. When sewage is discharged beneath the surface of a quiet body of water, currents are set up which help to produce an intermixture between the two fluids. The force of these currents varies directly with the velocity of the discharging current and the volume of discharge, and is helpful in bringing about dispersion and diffusion. When sewage is discharged beneath the surface of a quiet body of water of practically the same specific gravity, it does not intermingle immediately with the surrounding water. Some diffusion takes place from the outside edges

of the discharging stream, but intermixture seems to proceed chiefly after the discharging stream has lost its initial velocity. It is obvious from these facts that the velocity is an important factor in the mixing process.

If directed vertically upward from a submerged outfall, a discharging stream of sewage flows toward the surface of the water in a gradually enlarging column. Arrived at the top, the sewage spreads out thinly over the surface. Diffusion gradually takes place downward from this surface. If discharged horizontally from a submerged outfall, the sewage stream at first preserves its integrity for a considerable distance and then, rising upward, spreads out in a thin layer at the top of the water. Diffusion takes place in this case downward from the gradually enlarged column and from the surface layer, as when sewage is directed vertically upward from a submerged outfall.

When sewage is discharged into a quiet body of tidal water consisting of 40 per cent. land water and 60 per cent. sea water, it rises toward the surface irrespective of the direction of the discharge from the orifice, and spreads out upon the surface in a thin layer. The upward motion is not retarded perceptibly when the discharge takes place at a velocity of $1\frac{1}{2}$ feet per second into quiet water.

The shape of the discharging column of sewage is larger and longer when the discharge takes place in a horizontal direction than when the discharge is upward or downward, and for this reason, a horizontal discharge facilitates diffusion. To secure the most prompt and thorough intermixture, the sewage should be discharged in a horizontal direction near the middle and at the bottom of a tidal channel and in a direction perpendicular to the direction of flow of the current.

Three conditions are desirable in order to accomplish satisfactory diffusion:

1. The diameter of the discharging column of sewage should be small.
2. The velocity of the discharging column of sewage should be great.
3. The current into which the sewage is discharged should be rapid.

58 Investigations in Boston Harbor.—The water in the vicinity of the Boston, Mass., outlets was analyzed by the Metropolitan Sewerage Commission of New York during the month ending September 18, 1911. The analyses were intended to show the amount of dissolved oxygen in the water, the salinity and temperature being determined at the same time. The examinations covered the inner and outer harbor and there were special studies made of the three main outlets. The total number of analyses was 388. The method employed, the analyst and the floating laboratory were the same as had produced the large amount of information concerning the oxygen in the waters of New York harbor.

The condition of Boston's inner harbor, as measured by the dissolved oxygen was, in the main, very satisfactory, although there

were some places where the circulation of tidal water was insufficient to carry away the sewage which was discharged. The outer harbor, except in the immediate vicinity of the three main sewer outlets, contained an abundance of dissolved oxygen.

The conditions surrounding the Peddocks Island outfall were better than those found at Deer Island or Moon Island. It became apparent that the sewage began to be dispersed and diffused from the moment it left the outfall at Peddocks Island. The shape of the ascending column of sewage was somewhat like a funnel with incurved sides and broad flare. At a distance of 500 feet from the center, there was 7 per cent. of sea water mixed with the sewage at the surface. There was 3 per cent. 10 feet below the surface and 1 per cent. 15 feet below the surface. At 1,000 feet from the center there was no sewage below 10 feet beneath the surface. At 2,000 feet there was no sewage below 2 feet beneath the surface.

The amount of oxygen present varied with the concentration of sewage. At a distance between about 700 feet and 1,700 feet from the center of the sewage field, there was a considerable increase in the exhaustion of oxygen.

Submerged Outlets for Manhattan and Brooklyn.—For the discharge of sewage from Manhattan and Brooklyn it is desirable that submerged outfalls should generally be employed. In some cases they should extend sufficiently far from the outer ends of the piers to obtain the advantages of great depth of water, high velocity of tidal current and remoteness from observation.

The types of construction suitable for carrying the sewage to the bottom of the main tidal channels must differ according to local circumstances, particularly the depth of water and character of the bottom, whether of silt or mud or rock. In the Lower East river the currents are so swift and the bottom so hard and the traffic so great that submerged outfalls can be constructed only with difficulty. On the Hudson river side of Manhattan Island, the 59 & 60 conditions are more favorable and for this area a type of outfall has been designed.

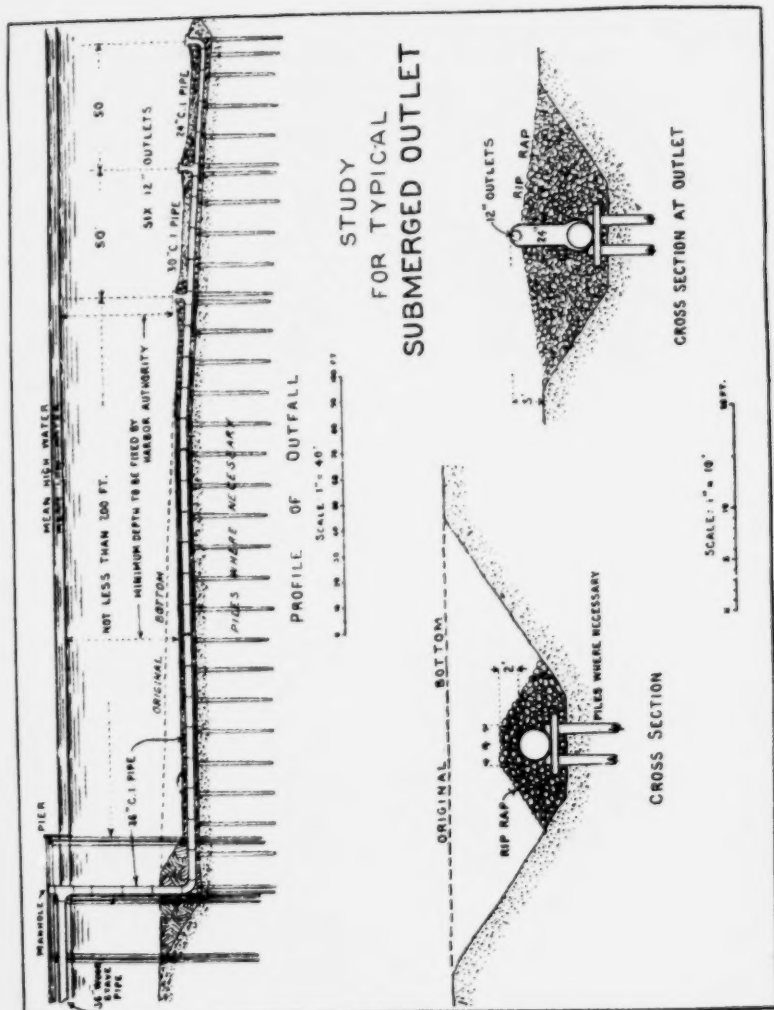
The capacity of the type of outfall which is here outlined for the Hudson river side of Manhattan Island can be increased beyond that mentioned, although the sizes given will be found economical to construct and it may be undesirable to collect more sewage to a single point for disposal than can be discharged through one outfall of this type.

The plan is to carry the sewage through a 36 inch wood stave pipe laid beneath a pier to a point near its outer extremity. The wood stave pipe would be joined at its outer end by a 36 inch cast iron pipe which would be placed vertically and extend to the bottom of the water. At the top a manhole would be provided for easy access for inspection, cleaning and repairs.

At the bottom of this vertical leg the 36 inch cast iron pipe would turn and run out into the tidal channel for a distance of not less than 200 feet from the outer end of the pier. At this distance there would be a short riser of 24 inch pipe, provided with two 12 inch

(Exhibit No 202)

PLATE VIII



outlets which would discharge in a direction parallel to the main line of the pipe and perpendicular to the direction of the tidal currents.

From the riser just mentioned, the cast iron pipe, now reduced to 30 inches, would extend 50 feet further from shore to a second riser similar to the first. From this point the cast iron pipe reduced to 24 inches in diameter would extend the final 50 feet to its outer limit, where it would be joined by a third riser to discharge the remaining sewage, as in the first two cases.

The cast iron pipe would, where practicable, be laid in a trench dredged in the bottom. Where the support was poor or uncertain, piles would be driven to carry the pipe. The pipe would be covered with a light filling of rip-rap and the trench filled. The minimum depth at which outfalls of this character should be constructed would have to be fixed by the Harbor Line Board. Apparently there is a depth of water in the Hudson river along the Manhattan shore at practically all points sufficient to permit this form of construction to be adopted. A study for a submerged outfall is shown in Plate VIII, following page 60.

The submerged outfalls would be for the dry weather flow of sewage. Storm water would be overflowed under the piers. The dry weather flow of sewage would generally be carried to the submerged outfalls by pumping.

(Here follows Plate VIII, Exhibit No. 202.)

61

IV.

Opinion of U. S. Engineers on the Proposed Island.

Recognizing that responsibility for the maintenance of a proper depth of water for navigation in the harbor rested with the U. S. War Department and that the island proposed by the commission for the disposal of the sewage of the Lower East river could be constructed only with the permission of that Department, application was made to the Secretary of War requesting the views of the War Department with respect to this subject. The commission's application was referred by the Secretary of War to the Chief of Engineers, U. S. Army, and by him to the New York Harbor Line Board for report.

The New York Harbor Line Board consists of Colonels W. T. Russell, W. M. Black and S. W. Roessler of the Corps of Engineers, U. S. Army. The island would be in that part of the harbor which is under the special jurisdiction of Col. Roessler, who has had much experience with breakwaters and other structures intended to resist the destructive action of the sea. The Harbor Line Board gave a hearing on the commission's project on March 7, 1913. On that occasion the subject was thoroughly discussed, plans, charts and profiles of the proposed structures being produced.

The opinion of the Harbor Line Board was transmitted to the commission by the War Department on March 22, 1913. It was to the effect that an island in either of the two locations suggested by the commission, one of which is shown on Plate I, following page 48 of Preliminary Report VI of the Metropolitan Sewerage Commission, would not interfere unduly with navigation nor have an unfavorable effect upon the harbor. In this opinion the Chief of Engineers concurred.

The correspondence in full follows:

February 18, 1913.

Hon. Henry L. Stimson, Secretary of War, Washington, D. C.

SIR: In making plans for a sanitary disposal of the sewage of New York City, it has become desirable to consider the practicability of constructing an island near the entrance of New York harbor. The island would be located on one of the shallow, sandy bars which are divided by the Fourteen Foot Channel to the north of Ambrose Channel.

62 The island would be constructed with an enclosing wall of rip-rap and a filling of sand or other solid material, the total area occupied being less than 30 acres. Upon the island would be tanks and other structures in which much of the solid matters of the sewage would be removed to be carried to sea in boats or disposed of in some other acceptable manner, while the clarified effluent would be discharged into the surrounding water through outlets so arranged as to insure its prompt dispersion and disappearance. The sewage, amounting to about 200,000,000 gallons per twenty-four hours, would be brought to the island through a tunnel.

Recognizing the authority which is exercised by the general gov-

ernment over the navigable waters, this commission desires to place its project in sufficient detail before you, to the end that an early determination may be reached as to the permissibility of constructing and using this island in the manner, and for the purpose, stated.

Members of this commission will be pleased to call upon you with reference to the subject in case you visit New York, or they will go to Washington to see you, if preferable. The technical details of this plan can be laid before such army engineer, officer or officers of the New York Harbor Line Board as you may designate.

Your early attention to this subject is requested in order that the result of your consideration may be known in time to be used in a report soon to be issued by this commission.

Respectfully,

GEORGE A. SOPER,
JAMES H. FUERTES,
H. DE B. PARSONS,
CHARLES SOOYSMITH,
LINSLEY R. WILLIAMS,
Commissioners.

March 3, 1913.

Mr. George A. Soper, President, Metropolitan Sewerage Commission,
17 Battery Place, New York City.

DEAR SIR: 1. The Harbor Line Board has before it your application of Feb. 18 to the Secretary of War concerning the construction of an artificial island near the entrance to New York harbor, and also a letter of Feb. 19th from Mr. H. de B. Parsons, Consulting Engineer, requesting that this matter be laid before this Board. In order that the Board may be able to come to a definite conclusion in the case, it is requested that you submit more detailed plans and make a definite application for such construction.

63 2. The Board desires to take this matter up at 10 a. m. on March 7th and it is requested that these plans be submitted before this time and that if possible you or your representatives be present to confer with the Board in the matter on that date.

Very respectfully,

WILLIAM T. ROSSELL,
Colonel, Corps of Engineers, Senior Member of Board.

March 6, 1913.

Colonel William T. Rossell, Corps of Engineers, New York Harbor Line Board, Army Building, New York City.

DEAR SIR: Your letter of March 3, relating to the proposal of this commission to construct an island near the mouth of New York harbor, has been received.

Application is hereby made for permission to construct and maintain an island for the treatment and disposal of sewage in accordance with the following plan:

The object of constructing the island is to afford opportunity for the treatment and final disposition of a quantity of sewage from the inner harbor sufficient to relieve and protect the inner harbor from its excessive burden of pollution.

The location proposed for the island is in shoal water, preferably

in latitude $40^{\circ} 32' 02''$ N, longitude $73^{\circ} 59' 46''$ W, or in latitude $40^{\circ} 31' 26''$ N, longitude $73^{\circ} 58' 21''$ W.

In plan, the island would be approximately rectangular except that the seaward side would be rounded. The area at the start would be about 20 acres of filled land and about 10 acres of harbor for the protection of vessels engaged in transporting supplies to the island and taking sludge and other materials away.

The outer face of the island will be a wall of rip-rap composed of large pieces of broken stone carried to the site on boats and laid upon the hard sandy bottom. It is expected that some settlement will at first occur, due to the water cutting sand away from under the stone. The main bulk of the island will be composed of sand supplied from a suction dredge which will take its supply from the bottom of the sea, or earth, ashes and other suitable material.

The height of the island above mean low water will be about 18 feet. The length of the island, when first constructed will be about 1,300 feet and the width 1,000 feet. The side of the rip-rap wall which is exposed to the sea will have a slope of 1 vertical upon 3 horizontal and the two adjoining sides will have an outer slope of about 1 on 2. The rip-rap will be 15 feet across the top and

64 will be surmounted by a concrete parapet wall 4 feet in height. The rip-rap will be from 75 to 122 feet wide on the bottom, according to the location with respect to the sea.

The island will contain a plant of settling tanks in which the sewage will have an opportunity to settle and deposit its solid matters during a period of about two hours. These tanks will be modified Dortmund tank construction, similar to those recently constructed at Toronto, Canada. Provision can be made for treating the sewage, if necessary, with a coagulant before passing it into the tanks.

After treatment, the sewage will be discharged through a number of outlets arranged radially from the island in such position as to bring about the most immediate and perfect dispersion of the sewage practicable. If desirable, it will be feasible to pump sea water and mix it with the sewage before the discharge takes place. Such admixture would facilitate the immediate diffusion of the sewage in the sea water; but the active agitation and free movement of the great volume of water in the vicinity of the island will, it is expected, make a preliminary mixture of sea water and sewage by pumping unnecessary.

The material which will settle out of the sewage in the tanks will be carried to sea in vessels and dumped sufficiently far from the land to insure that no trace will reach bathing beaches, inhabited shores or oyster grounds.

Provision will be made for a laboratory and dwelling house for those who will be needed to operate the tanks and other devices for the treatment and discharge of the sewage. It will be feasible to maintain a light on the island for the benefit of navigation, in case this is desirable.

In course of time, it will be necessary to increase the size of the island and it is proposed that this will be done by extending its

length so that the total area covered will be about three times that of the original island, or, approximately, 70 acres.

The quantity of sewage which will be brought to the island at the beginning is estimated at about 203,000,000 gallons per 24 hours during dry weather. During storms, this volume will increase about 100 per cent. This sewage will be collected from those parts of Manhattan and Brooklyn whose drainage is naturally tributary to the Lower East river between the Battery and 28th street, Manhattan. It is proposed to collect the sewage by building intercepting sewers close to the water front to receive the sewage from the existing combined sewers and gather it to a central pumping station to be located near the Brooklyn Navy Yard. A siphon built beneath the East river, will carry the sewage of Manhattan to the Brooklyn side. At the central pumping station the sewage will be pumped through a force main built as a tunnel to the island. The tunnel will be over 20 feet beneath the bottom of the Lower bay and so be free from injury to anchors even in the deepest parts of the channel between the island and the mainland where vessels rarely anchor. The sewage will consist of the ordinary dry weather flow except at periods of rainfall when the storm water from the streets will also be received to the extent of about once the volume of the average hourly production of house sewage.

65 All the sewage which is sent to the island will have been passed through grit chambers and screens with openings not larger than one-half inch. The sewage from Manhattan will be screened before passing to the Brooklyn side. Since it will be relatively fresh, it is estimated that no less than 15 per cent of the suspended matter will be extracted. Grit chambers will be located near the screens and their efficient operation will be insured by the necessity which will exist for removing the readily settleable material from the sewage in order to prevent obstructions in the siphon and interference with the pumps. The Brooklyn sewage will be passed through screens and grit chambers no less effective than those of Manhattan before the sewage is pumped through the force main. It is estimated that the settling basins on the island will remove at least 60 per cent of the suspended matter from the sewage. It is expected that the total effect of the treatment by grit chambers, screens and settling basins will be to remove considerably more than 75 per cent of the suspended matter originally present.

It is believed by this commission that either of the two locations here proposed for the island will be favorable for the sanitary disposal of the sewage and will be free from objection from the standpoint of navigation. Both sites are upon sand reefs where no vessels except fishing craft of lightest draft are likely to pass. The area of the island, even when extended to the dimensions which may ultimately be necessary, will be so small, as compared with the total area of the Lower bay, as not seriously to interfere either with the tidal prism or with the force or direction of the tidal currents flowing in and out of the harbor. The amount of solid matter contained in the sewage when discharged will be slight as compared with the volumes of water in the vicinity of the island and the action of

the waves and currents in this part of the harbor are so active that it seems improbable to this commission that deposits of any serious extent would be formed, even if the sewage was to be discharged in crude condition.

Apart from permission to build the island, which this commission would interpret as expressing a belief that no interference would be caused by the island to navigation, this commission would value the opinion of the Harbor Line Board as to the probable capacity of the island to resist the destructive action of the sea. It is recognized that the Army Engineers possess the qualifications of experts on this subject. If material criticism can be brought against the proposal of this commission for the construction of the island on the score of structural defect, suggestions looking to a more durable form of construction would be regarded in the light of a public service.

Accompanying this letter is a chart of Lower New York Bay, showing the two alternative locations for the proposed island, a profile giving the line of the tunnel through which the sewage would be pumped to the island, a plan of the island and three cross sections of the retaining walls.

Respectfully,

GEORGE A. SOPER, *President.*

66

March 22, 1913.

Hon. George A. Soper, President Metropolitan Sewerage Commission, 17 Battery Place, New York City.

SIR: Referring to your letter of the 18th ultimo, submitting, for the views of this Department, a proposition of the Metropolitan Sewerage Commission of New York, as part of a plan for the disposal of the sewage of New York City by the construction of an island in Lower New York bay, I beg to inform you that the New York Harbor Line Board, to which the matter was referred, reports under date of 15th instant, as follows:

"The Board is of the opinion that an artificial island in the Lower bay between Coney Island and Sandy Hook in either one of the two locations shown on the map, and with the dimensions across the direction of the bay and flow of the tide substantially as shown, will not interfere unduly with navigation, nor have an unfavorable effect upon the harbor. Before issuing a formal permit it is suggested that the Sewerage Commission be requested to submit a map showing the approximate position and size of the island it proposes to build at the present time and proposed future enlargement, and the location of the sewers between it and the shore; also such details of the plan of the settling basin or other means for clarifying the sewage as may be necessary to show whether or not such plan will effectually prevent solid matter escaping into the channel in undue amount; also a profile of the proposed sewer showing the depth below low water along its entire route and beyond the crossing of Coney Island Creek."

The Chief of Engineers concurs in the views of the Harbor Line Board, and the map referred to showing dimensions, etc., is transmitted herewith.

Very respectfully,

ROBERT SHAW OLIVER,
Assistant Secretary of War.

a COMPLAINANTS' EXHIBIT No. 203. James D. Maher, Commissioner.

NEW YORK CITY, May 19th, 1913.

This certifies that a copy of the within report has been filed in the Mayor's office by the Metropolitan Sewerage Commission.

JAMES MATTHEWS,
Executive Secretary.

Preliminary Reports on the Disposal of New York's Sewage.

VII.

Critical Reports of Dr. Gilbert J. Fowler, of Manchester, England, and Mr. John D. Watson, of Birmingham, England, on the Projects of the Metropolitan Sewerage Commission with Special Reference to the Plans Proposed for the Lower Hudson, Lower East River and Bay Division.*

Metropolitan Sewerage Commission of New York.

George A. Soper, James H. Fuertes, H. de B. Parsons, Charles SooySmith, Linsly R. Williams, Commissioners.

February, 1913.

1 *Report of the Commission Introducing the Reports of Messrs. Fowler and Watson.*

Honorable William J. Gaynor, Mayor of the City of New York:

SIR: The reports here published represent critical studies by eminent experts who were called upon by the Metropolitan Sewerage Commission in the autumn of 1912, to examine various projects which the commission was considering for the protection of the Harlem and Lower East rivers against excessive pollution by sewage.

Preliminary plans had been prepared by this commission for the disposal of the sewage tributary to these bodies of water, but owing to the radical character of the remedies which seemed to be necessary, and the large sums of money involved, this commission considered it desirable to subject the projects to competent and unprejudiced criticism.

Messrs. Fowler and Watson were requested to come to New York and study the data which had been collected by this commission, remain long enough to become personally acquainted with the situation and to weigh the relative merits of the alternative plans which

*This report is issued in advance of the final report of the Metropolitan Sewerage Commission in order that the contents may be of early service.

had been made to improve the situation. The two experts came to America separately and made their studies independently of one another, although, while still in New York and, later, in England, they met and exchanged opinions.

Dr. Gilbert J. Fowler, who came first, is a chemist. He is a Doctor of Science, Fellow of the Institute of Chemistry, Fellow of the Royal Sanitary Institute of Great Britain and author of numerous reports, papers and contributions to the science and art of sewage purification. The sewage disposal works of Manchester, England, of which he is superintendent, have been developed under his direction until they constitute the largest plant of their kind in the world. These works include screens, settling basins, contact beds, sludge storage reservoirs and steam vessels for transporting the sludge to the open sea.

Mr. John D. Watson, who is a Member of the Institute of Civil Engineers of Great Britain and a Fellow of the Royal Sanitary Institute, is an eminent consulting engineer and expert in sewage disposal. He is in charge of the sewage purification works for Birmingham which are as large and efficient as any of their kind. Originally consisting of farm lands, where the sewage was taken for disposal in the hope of utilizing its manurial properties, these works have been rebuilt by

2 Mr. Watson in accordance with modern scientific principles and include settling basins, sludge-digesting tanks, supplementary settling basins, percolating filters, screens and sludge-drying beds.

These two reports, which are of similar scope, therefore approach the subject from the separate standpoints of the chemist and the engineer. Each recognizes the necessity of stopping the existing pollution and improving the harbor without loss of time and critically discusses the nature and extent of the works which will be required. In each report the conclusion is reached that a large part of the sewage which is tributary to the Lower East river and Harlem should be collected in large sewers to be constructed near the water front and carried by tunnel to an island to be constructed in the sea at the mouth of the harbor, there to be discharged after enough of the impurities have been removed to insure that no nuisance or injury to health will result. This project was reported upon by the Metropolitan Sewerage Commission under date of January, 1913.

The standard of cleanness proposed by this commission in its report of August, 1912, is approved by Dr. Fowler and Mr. Watson as a code of minimum requirements. Mr. Watson, like some other sanitary experts who have been called upon to advise in regard to this standard, would have the harbor waters kept cleaner than the commission's requirements demand. Dr. Fowler discusses the present pollution in considerable detail and gives much attention to the need of cleanness with respect to these waters. Both experts lay emphasis upon the fact that the pollution has reached large proportions and is rapidly increasing.

The opinion is expressed by both that if the digestive capacity of the harbor for sewage is not to become overloaded to the point of nuisance, it will be necessary to carry a large part of the sewage away

for disposal, it being beyond the range of practicability to purify it near where it is produced.

It is pointed out that sewage works which are capable of effecting a high degree of purification are so likely to produce odors and nuisance from flies that it is desirable to avoid the construction of such works within the city limits as far as possible. For this reason only such comparatively crude and simple processes as employ settling tanks, grit chambers and screens should be considered for installation on the shores of Manhattan Island and Brooklyn. There is no land anywhere within the limits of Greater New York upon which it would be permissible to construct works capable of purifying the sewage tributary to the Lower East river and Harlem by percolating filters, such as Mr. Watson employs at Birmingham, or contact beds like Dr. Fowler uses at Manchester, because of the nuisance which would result.

After discussing other alternatives, Messrs. Fowler and Watson arrive at the conclusion that the proper solution of the problem is this commission's proposal to carry the sewage which is naturally tributary to the Lower East river, and eventually that which is tributary to the Harlem, to an island to be built at sea. On this island the sewage would be passed through settling basins and perhaps treated with electrolyzed sea water, in accordance with a method with which the Metropolitan Sewerage Commission has made some experiments. The effluent from the island should be discharged in such a way as to cause the organic matters present to be thoroughly mixed with large quantities of fresh sea water and, consequently, oxidized and rendered permanently harmless and inert by natural agencies.

Neither Dr. Fowler nor Mr. Watson has been dissuaded from endorsing this project on account of its cost. Their opinion is that the money for such sewage works as are necessary for the health, welfare and reputation of the port will be forthcoming, when once their necessity is understood. It is pointed out that other cities, and among them many small places, have spent much more per capita for sewage disposal than would be required here.

Mr. Watson has given considerable attention to the form of administration which is most suited for the construction and maintenance of the necessary main sewers and sewage disposal works and his experience as Chief Engineer of the Birmingham, Tame and Rea District Drainage Board, which represents a number of municipalities in addition to Birmingham, gives him special qualifications to deal with this subject. He recommends that a commission be created which shall have charge of the building and maintenance of such sewage disposal works as are necessary for New York and in this suggestion, Dr. Fowler, with a knowledge of the details of the recommendation, concurs.

The reports of Messrs. Fowler and Watson contain so much that is of value from scientific and practical standpoints and their statements seem so capable of aiding the public to understand New York's large

and complicated problem of sewage disposal that their two reports are herewith published in full.

Respectfully submitted,

METROPOLITAN SEWERAGE COMMISSION OF NEW YORK.

GEORGE A. SOPER, *President*.

JAMES H. FUERTES, *Secretary*.

H. DE B. PARSONS.

CHARLES SOOYSMITH.

LINSLEY R. WILLIAMS.

February, 1913.

4 *Reports of the Metropolitan Sewerage Commission.*

1. Digest of Data Collected Before the Year 1908 Relating to the Sanitary Condition of New York Harbor; 87 pages; 1909.

2. Report on the Discharge of Sewage from the Proposed Passaic Valley Sewer of New Jersey; 7 pages; May 23, 1910.

3. Report on the Proposed Discharge of Sewage from the Bronx Valley Sewer; 10 pages; July 25, 1910.

4. Sewerage and Sewage Disposal in the Metropolitan District of New York and New Jersey; 550 pages; April 30, 1910.

5. Present Sanitary Condition of New York Harbor and the Degree of Cleanness which is Necessary and Sufficient for the Water; 457 pages; August, 1912.

Preliminary Reports on the Disposal of New York's Sewage:

6. I. Study of the Collection of the Sewage of New York City to a Central Point for Disposal; 16 pages; September, 1911.

7. II. Description of the Four Principal Drainage Divisions in that Part of the Metropolitan Sewerage District which Lies in New York State; 11 pages; November, 1911.

8. III. Study of the Collection and Disposal of the Sewage of the Jamaica Bay Division; 10 pages; November, 1911.

9. IV. Study of the Collection and Disposal of the Sewage of the Upper East River and Harlem Division; 17 pages; July, 1912.

10. V. Study of the Collection and Disposal of the Sewage of the Richmond Division; 21 pages; September, 1912.

11. VI. Study of the Collection and Disposal of the Sewage of the Lower Hudson, Lower East River and Bay Division; 58 pages; January, 1913.

12. VII. Critical Reports of Dr. Gilbert J. Fowler of Manchester, England, and Mr. John D. Watson of Birmingham, England, on the Projects of the Metropolitan Sewerage Commission with Special Reference to the Plans Proposed for the Lower Hudson, Lower East River and Bay Division; 33 pages; February, 1913.

5

Report of Gilbert J. Fowler, D. Sc.

To the President and Members of the Metropolitan Sewerage Commission of New York.

GENTLEMEN: In accordance with the request of the Metropolitan Sewerage Commission, conveyed to me by the President, Dr. George A. Soper, in a letter dated September 27th, 1912, I arrived in New York on the 10th November, 1912, and remained, with brief absences in Boston, till Wednesday the 27th November.

During this time the following inspections were made:

- By water: 1. Upper bay,
2. East river to Long Island sound,
3. Round Manhattan Island,
4. Through the Narrows to Far Rockaway and into Jamaica bay.
- By land: 5. To Gravesend bay, Coney Island, Sheephead bay and Canarsie, visiting disposal works at Sheephead bay, Paerdegat basin and 26th Ward,
6. To Newtown creek, returning to Manhattan, recrossing the Lower East river below Hell Gate and skirting the edge of the Upper East river including Steinway, Flushing bay, Whitestone and Douglaston.

I also visited Boston, and through the courtesy of the Massachusetts Board of Health, was able to inspect the three types of sea outfall there. The same day I visited the Lawrence experimental station and discussed the work being done with the chief chemist. On these various expeditions numerous photos were taken of important points such as some of the larger sewer outlets, proposed places of discharge &c.

A good deal of time was spent in the laboratory of the commission overlooking and discussing experiments on the possibilities of electrolysed sea water as a precipitating and sterilising agent for the sewage. I also had much conversation and discussion with reference to the data accumulated by the commission, and was shown numerous data hitherto unpublished, especially in reference to the possibilities of complete nitrification taking place in mixture of sea water and fresh water.

6 The President was good enough to demonstrate for me the method used by the commission in their fundamentally important work on the dissolved oxygen in New York harbor. The method is rapid and accurate and well suited to the conditions of investigation. I have carefully studied both before and since my visit to New York the extensive and valuable reports issued by the commission as well as the report by Major Black and Prof. Phelps.

Immediate Conclusions.

I was impressed at the outset by the vastness and complexity of the problem to be dealt with. London may have a larger present population but the conditions for discharge are infinitely simpler.

In addition to the rapidly increasing population directly or indirectly discharging its sewage into the harbor, the problem is complicated by the outstanding facts, viz:—(1) the growing scarcity and value of unbuilt upon land in the vicinity of the harbor, (2) the comparatively small amount of water available for flushing out the bay, this being limited practically to the flow of the Hudson. The thickly populated districts abutting on the Harlem river and the Lower East river discharge into waters which ebb and flow with the tide, but suffer very little actual change, little or no excess water passing out of the bay or into it at each tide.

As a consequence, the conditions to be met with in the Harlem and Lower East rivers call for immediate action. Not only is the bottom polluted, but the water, even in favorably situated portions of these rivers, is deficient in oxygen, in the majority of cases to nearly 50 per cent. In many places there are local nuisances already, and floating faecal matter, paper, &c., are in frequent evidence. What the conditions are likely to be when the surrounding districts, increasing as they are now doing, to say the population of 1940, it is not pleasant to conjecture. It is evident that something will have to be done here and done at once. When the volume of sewage to be dealt with, over 350 million gallons per day at the present time, and more than 700 million gallons by 1940, is considered it is evident that for this section of the work alone considerable expenditure will have to be faced.*

In view of the very large expenditure involved, it is difficult to exaggerate the importance of adequate preliminary studies and the work of the commission throughout appears to me to be a model of the way in which such investigations should be carried out.

7 The conditions are so complicated, owing to the diversified character of the land and water areas constituting New York harbor and its surroundings, that endeavors to reproduce them artificially, as is often done in research work, are likely to be only partially successful. The method of thoroughly studying the actual state of things obtaining in the bay and other waters in the vicinity under all conditions of season, tide and weather, as has been done by the commission, seems the only possible one, and the work has been done with masterly completeness. No question necessary for the formation of a right judgment on the questions which should be settled at this time appears to have been left unstudied by the commission.

The citizens of New York may rest assured that the large sum of money they will be called upon to pay for the protection of their harbor will not be asked for except as the result of opinions formed

* Report Metropolitan Sewerage Commission of New York, August, 1912, p. 28.

after years of study much more complete than is generally given to such a subject. Every year, however, the conditions now existing must necessarily grow worse and, while in the case of a growing science like that of sewage disposal it is well to hasten slowly, yet through the labors of the commission there will exist no justification on the score of imperfectly known data for postponing certain most necessary works.

Principles Governing Consideration of the Problem.

The conditions which must be realized if the constituents of sewage are to be rendered inoffensive or finally mineralised are essentially the same whether the disposal be by irrigation upon land, filtration through artificial biological filters, or dilution with fresh or salt water. The process is in all cases one of oxidation, i. e., practically speaking, combustion, and if it is to be conducted without nuisance, enough oxygen must be present at all stages of the process to prevent the formation of evil smelling products.

It is perfectly legitimate to use the oxygen dissolved either in sea or river water in order to oxidise sewage. Under proper conditions of discharge, complete transformation and mineralisation of the sewage matters can be effected in this way with less nuisance than often accompanies treatment on filters or on land.

The question of the margin of safety which should be allowed if nuisance is to be avoided has been the subject of reports by a number of well-known experts to the Metropolitan Sewage Commission * and all of these reports agreed that under no circumstances should the dissolved oxygen in the harbor be allowed to sink to below 50 per cent. of saturation. In this opinion I concur. It will, however, be most unwise to be content with a margin simply sufficient to barely eliminate nuisance.

Two main considerations govern the situation from the point of view of public policy; these may be described as considerations of Health and Welfare.

Health.—There are obvious ways in which public health may be directly affected by the filthy conditions of parts of the harbor or even by the apparently innocuous discharge of sewage or sewage effluent.

It is not a pleasant sight to see numbers of floating faeces washing in and about piers where food supplies are landed from lighters some of which have a low free board. Gulls and flies may also quite possibly be carriers of infectious material under such conditions.

The question of oysters is of more direct importance. Even if sewage or sewage effluent is actually sterilised, the growth of oysters near an outfall is always a possible source of danger, and while it is quite easy to exaggerate this, yet it can never be in accordance with right sanitation for an article of food to be thus contaminated.

The pollution of bathing sites has been dealt with at length by

* Report Metropolitan Sewerage Commission of New York, August, 1912, pp. 69-164.

the commission.* The conditions which at present exist are unsatisfactory in the extreme.

The carrying of polluted driftwood daily into the homes of the poor in the neighborhood of the water front does not tend to raise the standard of cleanliness in such homes and should be prevented rather by stopping pollution than by forbidding what is in itself a reasonable and thrifty proceeding.

But even more important than the direct and obvious ways in which the public health is affected by the polluted condition of the harbor waters, is the practically unconscious lowering of that sense of decency and cleanliness of living which must be maintained if the efforts of social reformers are to have any serious result.

Crowds of people from the poorer quarters of New York throng the recreation piers and pleasure drives on the water front. If it is obvious to them that those in authority, who have the power, are yet unconcerned to abate uncleanly surroundings, the already not inconsiderable effort required to maintain a decent spot of home life in a mean environment, will be rendered even harder to achieve.

Welfare.—The second consideration, viz., that of welfare, as it has been termed, is perhaps less obvious, but is most important when expensive works, the use of which is partly for future generations, have to be considered.

9 A study of the history of sanitation, such for example, as was possible in the historical section at the International Hygiene Exhibition in Dresden in 1911, will show that, up to comparatively recent times, conditions were tolerated which to us would seem unspeakable. Yet even now the standard of requirement is constantly rising. One may, indeed, frankly say that the modern American bathroom both in its fitting and the frequency with which it is to be found is a distinct advance upon what is common even in England. Such a bathroom, however, increases the difficulty of the sewage problem, and in looking forward to the future, similar advances in public requirements must always be reckoned with. The idealism manifested in such great buildings as the Pennsylvania Railroad station and the Metropolitan Museum of Art and the parks and playgrounds of the city will find its further development in a demand for brightness and beauty in the surrounding water spaces. Nor is such idealism unrelated to mere purely economic prosperity. The true solution of any problem is true at all points, sanitary, æsthetic, ethical and economic.

Apart from the question of affecting the vitality, and consequent wage earning capacity of the people, the reputation of a port is a very essential factor in its commercial prosperity. The condition of the Clyde and of the Manchester ship canal was for many years a by-word. The great sewerage and sewage disposal works at Glasgow carried out at a total cost of over £2,000,000 for 800,000 people have been the means of rehabilitating the reputation of the Clyde

* Report Metropolitan Sewerage Commission of New York, April 30, 1910, pp. 486-497.

and adding to the amenities of life, pleasure trips being now possible from the Bromielaw to the Firth of Clyde.

The large amount of money spent on sewage works in the watershed of the Mersey and Irwell is, apart from the increasing expenditure of Manchester itself, slowly but steadily improving the water of the Manchester ship canal.

At one time the stench from the polluted Thames in hot weather rendered the committee rooms in the houses of parliament in London uninhabitable. By the removal of the sewage to treatment works and outfalls lower down the river this nuisance has been abolished, and London is now one of the healthiest and best drained cities in the world.

In the case of the three cities above referred to, their works were carried out under urgent pressure of obvious and almost intolerable nuisances from the polluted streams. New York should deal with her problem before such acute conditions arise.

The foregoing general view of the situation clearly indicates that any scheme which is decided upon must not block the commercial avenues of the future. It must be so designed as to be capable of expansion as the needs of the city increase.

10 Possible Methods of Dealing with Sewage.—The various possible methods which are available for dealing with sewage on the large scale may be broadly divided into:—

1. Direct discharge into water,
2. Discharge after screening,
3. " " sedimentation,
4. " " chemical treatment,
5. " " filtration in some form,
6. " " combination of processes.

The proportional amount of impurities removed by these processes depends on numerous factors, e. g., the freshness and strength of the sewage. Thus, screening will remove a much greater proportional amount from very fresh sewage than from sewage which has been mixed and churned up for many miles in a trunk sewer. Chemical treatment is more economical with strong sewage than with weak, and therefore is of less advantage with American sewage than with European.

Very roughly, it may perhaps be assumed that under the conditions existing in New York, of the nuisance-producing solid material in sewage capable of producing deposits of sludge, the following percentages can be removed by the respective processes:—

Screening and grit chambers.....	3-6 per cent.
Short sedimentation	50 "
Chemical treatment	75 "

None of these processes seriously affects matters in solution. Filtration affects not only the finely divided colloidal matter still present after the foregoing processes but also oxidises substances in solution.

Which of these methods can be used at any of the various proposed points of outfall in New York harbor is to be determined by local conditions. What these conditions are is considered in the next section.

The Present Polluted Condition of the Harbor.

Broadly, the waters of that part of New York harbor which lies in New York State may be considered separately as follows:—

The Hudson river,

The Upper bay,

The East river and the Harlem river.

Jamaica bay.

11 Of these, the Hudson river contains the most dissolved oxygen, this amounting to over 90 per cent. of saturation in the centre of the river in the northern part of Manhattan and diminishing to 60 per cent. near the Battery. The Hudson river supplies practically the only water available for flushing the harbor. All along the edge of the Hudson among the piers objectionable conditions exist.

The Upper Bay.—All the pollutions from the waters entering the harbor at certain states of the tide, as well as those resulting from direct sewer discharges are mixed by tidal currents in the Upper bay and a proportion of the solid matters is doubtless deposited there during the ebb and flow of the tide. This is evidenced by the polluted character of the dredgings from the bottom of the Upper bay at nearly every point of observation. Considerable deposit of sludge has been found south of Governor's Island.

The general appearance of the waters of the Upper bay is by no means attractive. Large fields of sleek, or oily film, are frequent and, more objectionable, are masses of floating debris in which large quantities of faecal matter are often entangled. The Gowanus canal is but little better than an open sewer, there being an insufficient circulation of water to dilute the large volumes of sewage discharged into it.

The East River and the Harlem River.—It is on these rivers, especially in the Lower East river and the Harlem that, as already stated, conditions exist which call for urgent remedy.

Large sewers discharge from the thickly populated districts on both sides of these waterways and there is little or no net tidal discharge. As a result, the bottom of the upper East river as far as Throg's Neck at the entrance to Long Island Sound is foul, and in the Lower East river, in places unaffected by the ebb and flow of the tidal currents, foul deposits occur.

In the Lower East river from the Williamsburg Bridge to Hell Gate the dissolved oxygen present, especially in the summer months is not much more than 50 per cent. of saturation.* In some parts

* In the summer of 1912 some samples of water from the Lower East river, near the Brooklyn Bridge, were found to contain 43 per cent. of oxygen.

of the Harlem river it is less than this. There are portions of the Harlem river already approaching the condition of the Manchester ship canal, while Newtown creek has practically reached that condition. In the vicinity of Wallabout basin there is a large sewer outlet which produces a small lake of sewage in its vicinity, which is most objectionable.

There is no doubt that if the sewage which now enters crude into the Lower East river and the Harlem river could be taken up and dealt with in a satisfactory manner, very great benefit would accrue not only to these waterways but also to the Upper bay and Upper East river into which much of the sewage eventually finds its way.

Jamaica Bay.—The characteristic feature of Jamaica bay and its vicinity is the growing summer population of numerous pleasure resorts, such as Bergen Beach, Arverne, Edgemere, Canarsie and Rockaway. The conditions which I saw in November were, therefore, hardly typical. Effluents from treatment works at Sheepshead bay and the 26th Ward, though obviously imperfectly purified were not the cause of serious visible pollution.

In view of the increasing population and of the schemes of harbor development which are being considered, it will be necessary before very long comprehensively to deal with the sewage which at present discharges into the bay.

The question of oyster pollution must here, also, be dealt with and it should be clearly understood that ordinary methods of treating sewage give little protection from a bacteriological point of view, while processes of sterilization may easily produce a false sense of security. It would seem best for oysters not to be taken near densely populated centres, as under such circumstances the chances of pollution, apart from the sewage which is discharged from actual sewage outfalls are considerable.

Proposed Remedies.

Sewage Tributary to the Lower East River and Harlem River.—As already emphasized, the first point of attack in dealing with the problem of purification of New York harbor is the Lower East river and the Harlem river, and I have given my most careful consideration to this part of the commission's work.

After much study the commission have concluded, and I think rightly, that the only point where large quantities of sewage can be treated in this neighborhood is at Ward's Island. It is possible to pick up the sewage which at present discharges into the Harlem river and also that which is turned out of the large sewer at Hunt's Point and bring it all to Ward's Island where it can be treated in settling tanks and the heavier sludge removed.

Some 124 million gallons daily would be thus dealt with at once, and over 400 million by 1940,* and would be discharged into the

*Preliminary Report IV. of the Metropolitan Sewerage Commission on the Disposal of New York's Sewage, July, 1912.

swift tidal currents at Hell Gate where the best possible conditions exist for mixing.

13 Sedimentation, however, leaves a large proportion of potential solids still present as well as all the impurities in solution. Treatment by chemicals instead of by plain sedimentation would remove a further proportion of the suspended impurities, but the treatment in this way of such large volumes of sewage as may be taken there involves numerous difficulties and greatly increased cost, which would weigh heavily against the advantages obtained. Further purification, by filtration, at Ward's Island is impracticable, and also not to be recommended so near large centres of population owing to the possibilities of aerial nuisance and fly trouble on large areas of filters.

It becomes matter, therefore, for careful consideration how far the concentration of the sewage to one point and discharge into the local waters after elimination of the grosser solids would really relieve the situation. It is to this point that most careful thought has been given and the bearing of all the available data studied under every aspect.

Owing to the fact that the waters rushing through Hell Gate only pass back and forth with the tide and do not really get away to the ocean, it is evident that whatever sewage is discharged at Hell Gate is largely dependent for its oxidation on the oxygen in the water with which it mixes in one tide. The Lower East river is, however, highly polluted and the discharged effluent will therefore not get much help from it. The situation, in fact, is only improved by the elimination of the grosser solids from the sewage of the Harlem district. If the situation is to be radically improved, the conclusion seems inevitable that some sewage must be removed from the Lower East river.

From figures supplied me by the commission, I calculate that if the sewage of the Harlem territory is collected and passed through settlement tanks on Ward's Island, and if the sewage of those parts of Brooklyn and Queens which would ordinarily discharge into the Lower East river be removed altogether, there will then be a dilution representing 1 of raw sewage to 200 of water in the Lower East river at mean low tide.

This is a considerable improvement on present conditions, representing a removal from the Harlem and Upper and Lower East rivers, together with about 50 per cent. of the total sewage which at present pollutes them.

It is, however, from the Manhattan waterfront that the greatest proportional volume of sewage enters the Lower East river. It exceeds the volume discharged into this division of the harbor from Brooklyn and Queens by about 50 per cent. The further conclusion, therefore, is forced upon one that a really satisfactory solution of the problem must involve the removal of this sewage also. Indeed a study of the statistics show that if this is not done, the Lower East river in 1940, will revert to a condition even worse than exists to-day.

14 Disposal at Sea of that Part of the Sewage of Brooklyn, Queens and Manhattan Which Would Ordinarily Discharge into the Lower East River.—The conditions discussed in the foregoing section show clearly that the sewage from these districts will have to be removed from the Lower East river if the situation is to be properly dealt with.

From the researches of the commission there would appear to be three possible outlets for this sewage.

The first possibility is to take it to Barren Island and there treat it in tanks, followed, possibly, by some form of filtration and discharge it near the entrance to Jamaica bay. At the same point would be collected the sewage now very imperfectly dealt with at the various sewage works discharging into the creeks on the northern shore of Jamaica bay. The point of outlet would be at the entrance to Jamaica bay.

Barren Island itself is, however, little more than half a mile from the large summer population on the Rockaway peninsula, and if, as is not at all improbable in hot summer weather, some amount of smell should arise from the filters, it is not far enough away to prevent a nuisance to these people. Moreover, the point at which the effluent would discharge is not half a mile from thronged bathing beaches. There are therefore these grave objections to an outlet near Barren Island.

A second alternative proposition has been considered, viz:—the removal of the sewage to the west side of Staten Island, with the erection of purification works there. Apart from engineering difficulties which I am informed exist in carrying so much sewage across the very deep channel of the Narrows, the conditions of final discharge would render purification by biological filters necessary, and similar objections would again arise in regard to nuisance from these as have been pointed out in regard to the Barren Island project.

Under these circumstances a third alternative has been suggested which seems to me to have much to recommend it. This proposition is to build an artificial island well out in the Atlantic, nearly three miles from the shore of Coney Island, and there construct settling tanks, and discharge the effluent after settlement of the bulk of the suspended solids, into deep water, with proper engineering precautions to ensure thorough mixing of the effluent with the seawater.

After inspection of the Boston sea outfalls I am clearly of the opinion that no point of outlet should be less than 40 feet in depth, and that the discharge should be continuous so as to minimize the quantity sent out in any interval of time.

The sludge deposited in the tanks could be readily taken
15 well out to sea in tank steamers of the pattern used in Europe, as at Glasgow, Manchester, Salford and London.

I understand that the island can be made without difficulty from the spoil and debris from excavations in New York city at present taken out to sea, or from sand pumped from the bottom of the sea.

I understand, also, that it will be possible to increase the number and length of the outfall pipes as more and more sewage is coupled up to the island, so that the effluent will always be well distributed in the sea water. The operations can be carried on without causing nuisance to any one, the conditions for sea disposal of sludge in tank steamers are very simple. The scheme is capable of indefinite expansion as more sewage is taken up, as the size of the island itself can be increased as extensions to the works are required.

Many matters rather of detail remain for further consideration in regard to the methods of treatment employed both at what may be termed "Atlantic" Island and Ward's Island. The design of the settlement tanks to be employed is a question of importance. A form of tank is to be preferred which would expose as little water surface as possible and also allow automatic removal of the sludge by the pressure of the supernatant water. A modified form of two-story tank would seem well suited to this purpose.

The sludge produced by the thorough fermentation which takes place in the so-called Emscher tanks, while greatly reduced in bulk and offensiveness, would offer some difficulties in carrying to sea, owing to its being saturated with gas. It is possible that judicious admixture with salt water would obviate this difficulty. In any event the disposal of sludge is not the least difficult part of the problem. There will not be more, for a long time at any rate, than is at present handled at the London outfalls, and the conditions of sea disposal are simpler in the case of New York.

For reasons indicated when referring to works on Ward's Island, I do not recommend treatment by chemical precipitants. I think, however, that very careful study deserves to be given to the practicability of adding a small dose of chlorine to the effluent, e. g., by the addition of a certain volume of electrolysed sea-water. This would serve the double purpose of deodorising what may be a somewhat malodorous effluent after its long travel through the sewers, and a further important advantage would lie in preventing an immediate call upon the dissolved oxygen in the sea at the point of discharge, and thus giving time for more thorough mixing and aeration to take place.

Some Further Problems.—There are many matters of importance, subsidiary to the large scheme outlined above which call for brief mention.

16 A system of screens and catchpits has been designed for Manhattan Island, which could afterwards be used for screening storm water, overflowing from the main sewers later to be built. It is in my view important that this should be carried out, in order that even after large sums have been spent on main sewers and outfall works, there should not be public disappointment, when visible pollution is seen to be present after every shower of rain. Before such refuse is removed, however, means must be at hand for its rapid incineration in suitably placed destructors.

The scheme of outfalls and outfall works designed by the commission for the districts abutting on the Upper East river seems to

me to be adequate, at any rate, for many years. The outlets are all in deep water and the conditions resemble those of the Clyde summer resorts or English lakes, where the sewage of a fairly large population is disposed of without serious difficulty.

Time did not permit me to study the problems connected with Staten Island actually on the spot. From a perusal of the commission's report on the disposal of the sewage of the Richmond Division there would not appear to be any special difficulty in dealing with the situation as far as regards the responsibility of New York City.

In the Arthur Kill and Kill van Kull we are approaching the problems of New Jersey. I have not been called upon to express an opinion on matters which are a subject of litigation. One may, however, safely say that a resolute handling by New York City of her own problems is likely to facilitate an equitable conclusion.

Summary and Conclusions.

After careful consideration of the situation as it has been placed before me I am of opinion that the sewage of the Harlem district should be collected and treated in sedimentation tanks on Ward's Island.

This will relieve the immediate and pressing situation on the Harlem river. It will, however, do little or nothing to improve the Lower East river.

It is of equal importance, therefore, that the scheme be pressed forward of driving a main sewer southwards through Brooklyn to an artificial island well out from shore in the Atlantic ocean, where tanks could be built for settling out the heavier suspended matters and removing them to sea.

Into this main sewer would first be discharged that part of the sewage of Brooklyn and Manhattan which at present passes in a crude state into the Lower East river. Later, more of the sewage of Manhattan should be coupled up to this sewer, the outlets at the artificial island being extended with each large increment of sewage.

17 Next, the sewage from the Jamaica Bay Division might be brought to the island and finally, if thought desirable, the sewage which, during all this time had received treatment at Ward's Island.

By this sequence of procedure the experience gained at Ward's Island would be of value in designing the final disposal at the "Atlantic Island," and at any rate a large proportion of the money expended in tanks, &c., at Ward's Island will have been redeemed before the works are abandoned. The expenditure in sewers in the Harlem district will be for permanent works alone.

The order of carrying out the various needful works and the time over which the construction should extend would all be matters within the control of the permanent commission suggested by my colleague, Mr. Watson, with whose views on this aspect of the question I heartily concur.

This same central board or commission would care for the other

less immediately pressing, but still highly important, problems referred to in the later paragraphs of the foregoing report.

The above represents in broad outline the lines upon which, in my opinion, the City of New York should proceed in its endeavour to obtain a harbor worthy of itself.

It must again be emphasized that no time should be lost in setting about the actual carrying out of the scheme. It must of necessity take a number of years to complete, and equally of necessity the condition of the harbor waters must become progressively worse if nothing is done, and will indeed probably be worse before the first instalment of the work is completed.

I am, however, confident that the citizens of New York will show the same determination and largeness of outlook already manifested in their great water supply projects, their colossal railway undertakings, and magnificent bridges and public institutions, in this further effort after social well-being, and will build the works necessary to cleanse the harbor and make it worthy in every respect of its great position as the Gateway of the West.

Respectfully submitted,

GILBERT J. FOWLER.

Manchester, February 10, 1913.

18

Report of John D. Watson, M. Inst. C. E.

To the President and Members of the Metropolitan Sewerage Commission of New York.

GENTLEMEN: I have given the problem of the sewerage and the sewage disposal of your great city my close and careful consideration during the past two months.

The fortnight which I spent in the city in the end of November and beginning of December gave point and animation to the study which was not otherwise possible, and I take this opportunity of thanking you for the ready access you gave me to all your documents, plans, and analytical figures, and for the facilities with which you provided me in the inspection of every part of the area which I thought it essential to visit. Allow me also to record my appreciation of the exhaustive preliminary investigations which you have made. These far exceed anything which I have hitherto had experience of, and the fact of your having printed them renders unnecessary reference to details which otherwise would have had to be given in this report.

The Polluted Condition of the Harbor.

If there were any prospect of limits being set to the bounds of New York, if there were any signs that sufficient accommodation had already been made for the shipping of the port, or if the waters of the harbor were so foul that the citizens had ceased to regard them as valuable for other than utilitarian purposes, the disposal of the sewage—vast as the volume of that is—would be comparatively easy.

But it is quite otherwise. The city is more than the capital of a country; it is the greatest city of a continent. The harbor is the gateway to the United States, and the noble rivers which find a ready outlet into it form, with the harbor proper, a port which affords at all stages of the tide no halting welcome to vessels of the greatest burden.

When I first had the pleasure of seeing the Hudson between Albany and New York, I was greatly impressed by its grandeur and its purity; when I motored along its left bank from Riverside Park toward the city boundary at Yonkers in brilliant sunshine, I thought it the Queen of Rivers, and I cannot believe that the average citizen would willingly allow it to become visibly polluted with sewage, yet the facts to which I shall refer will prove that it is necessary to take steps now to guard against such a contingency in the immediate future.

19 Visible Pollution.—The numerous analyses of the harbor waters made by your own officers, supported by men of such eminence as Professor Phelps, Dr. Adeney and Dr. Fowler, and the clear evidence of pollution which I have witnessed, lead me to the opinion that continuance of the present unhampered license to pollute can only lead to disaster. When it can be shown that even now the condition of the harbor in summer is obviously unclean, it is only a question of time when an ever-increasing population discharging an incremental amount of sewage and trade waste into what must be practically a stationary volume of harbor water will convert into a nuisance what should be one of the brightest and best of the city's possession.

One of my first actions in prosecuting this study was to investigate the condition of the harbor water, and even in the end of November I found at several places a slight smell of sewage. In ferrying across the river between 92nd Street and Astoria I observed innumerable particles of paper and even pieces of excrementitious matter in the water. Sea gulls indicated where the public sewers debouched directly into the river.

In many places in the East, the Harlem and the Hudson rivers, the Gowanus and Wallabout bays, visible evidence of the presence of sewage was only too apparent. Near the Battery I saw food which had just been unloaded from a boat that was moored in what looked more like sewage than clean water. At another place (Gowanus canal) I witnessed the ebullition of gas apparently arising from septitized sewage sludge. Large flows of greasy sleek and debris were to be seen at frequent intervals. Open ends of sewers spewing their filthy contents into the rivers are of much too frequent occurrence.

One and all demonstrate the same lesson that the time has arrived when a standard of cleanness should be set and maintained. If such conditions were offensive in November and December, it is obvious that they must be worse in the hot seasons of the year. Of course offensiveness to sight and smell do not necessarily constitute a nuisance which is dangerous to health, but as no self-respecting com-

munity would tolerate streets that were rarely scavenged because no injury to health could be traced to them, no port of the first rank should permit excrement paper, straw and grease to flow to and fro on the surface of the chief highway into the city because it could not be proved that a human being had died as the result.

The Proper Standard of Cleanness.—The standard of cleanness which you suggest, and which I heartily approve, should be reasonably but strictly enforced.* Liquid pollution, although less obtrusive, is not less in need of prevention, and it is in the interest of the community to see that any recognized standard which may be decided upon should be conscientiously adhered to. What the standard should be is a question which you have already submitted to a number of well known experts, and they have all united in saying that the dissolved oxygen in the harbor water should not be allowed to fall below 50 per cent. or 60 per cent. of the saturation limit. Colonel Black and Professor Phelps suggested that it should not be allowed to fall below 70 per cent. saturation, and this figure is more in accordance with my own view; indeed I go further and say that an even higher standard is feasible if the project recommended later in this report is approved and given effect to.

The result of 289 samples tested by you for dissolved oxygen in the summer of 1911 show clearly the polluted state of some parts of the harbor. Taking 100 per cent. as the saturation point, or the normal condition of clean water, the following comparison of average figures speak volumes:—

* Report Metropolitan Sewerage Commission of New York, August, 1912, page 70.

20

Standard of Cleanness.

1. Garbage, offal or solid matter recognizable as of sewage origin shall not be visible in any of the harbor waters.
2. Marked discoloration or turbidity, due to sewage or trade wastes, effluence, oily sleek, odor or deposits, shall not occur except perhaps in the immediate vicinity of sewer outfalls, and then only to such an extent and in such places as may be permitted by the authority having jurisdiction over the sanitary condition of the harbor.
3. The discharge of sewage shall not materially contribute to the formation of deposits injurious to navigation.
4. Except in the immediate vicinity of docks and piers and sewer outfalls, the dissolved oxygen in the water shall not fall below 3.0 cubic centimeters per litre of water.† Near docks and piers there should always be sufficient oxygen in the water to prevent nuisance from odors.
5. The quality of the water at points suitable for bathing and oyster culture should conform substantially as to bacterial purity to a drinking water standard. It is not practicable to maintain so high a standard in any part of the harbor north of the Narrows or in the Arthur Kill. In the Lower bay and elsewhere, bathing and the taking of shellfish cannot be considered free from danger of disease within a mile of a sewer outfall.

† With 60 per cent. of sea water and 40 per cent. of land water and at the extreme summer temperature of 80 degrees F., 3.0 cubic centimeters of oxygen per litre corresponds to 58 per cent. of saturation.

Lower New York bay.....	98	per cent
Long Island Sound near Throgs Neck.....	96	"
Hudson river, a few miles above Manhattan Island..	81	"
Narrows	73	"
Upper East river	71	"
Kill van Kull	66	"
Hudson river to north of Manhattan Island.....	64	"
21 Upper New York bay.....	63	per cent
Lower East river.....	55	"
Newark bay.....	54	"
Harlem river.....	42	"

Average figures in such a study do not quite suffice, for as the strength of a chain is the weakest link, so the lowest figures obtained (39 per cent at the lower end of the Harlem in July, 1911) indicate the danger conditions which sanitarians would strain every nerve to avert.†

The Increasing Discharge of Sewage.—When one remembers that the population of New York was only 2,500,000 in 1890, and that in 1905 it was 4,000,000, a careful estimate of its probable growth in the future is essential to arrive at a wise judgment in the matter of sewage disposal.

Estimates have been made by several authorities, including Freeman who said the population in 1940 would be..... 7,652,000
and Laidlaw who said it would be..... 8,662,829
The New York Telephone Company's estimate is..... 8,747,000
and the Board of Water Supply's estimate is..... 9,258,000

The average of these suggest a probable population of the city in 1940 of 8,580,107, a figure which proximates to your own estimate of 9,000,000, which be it remembered is based on the Census figure of 1910, and on this account is more likely to be accurate.

The prospective population which should be reckoned, however, is not 9,000,000 but 12,000,000, the population of the metropolitan area. The question as to what extent the harbor is likely to be burdened with impurities in 1940, assuming that nothing is done in the interval, depends on population more than anything else, and whether that population is located north, south, east or west of the harbor makes no difference. Artificial boundaries, therefore (state or other), are obviously not so important to the issue as watershed, and far fetched as it may appear to be at first sight the manner of disposing of the sewage of the City of Albany and every other populous place built and to be built on the banks of the Hudson will materially affect the problem under consideration. This will be apparent if it is conceded that the recuperative influence of the har-

†The percentage of oxygen fell still lower in 1912. The average for the year: Hudson river off Pier A, 55 per cent.; Narrows, 70 per cent.; Kill van Kull, 65 per cent.; Upper New York bay, 64 per cent.; Lower East river, 47 per cent.

bor depends very largely upon the purity or otherwise of the Hudson as it enters New York City.

22 The act of assimilation can be carried on only in the presence of oxygen, and it is therefore essential to conserve that oxygen as much as possible.

The table which I have quoted to show the relative state of purity at various specified places as measured by percentage of loss of oxygen is eloquent condemnation of the existing system, a condemnation which is only partially mitigated by the naturally and wonderfully even admixture of the harbor water as shown by the voluminous observations you have made.

In studying this question the fact that the volume of sewage must increase constantly has to be set in juxtaposition with the fact that the clean water from whence the oxygen is derived must remain very much the same in all time. Nor should the floating population as represented by the trade of the harbor be ignored. This is certainly a difficult problem, and I fear it will be impossible to exclude sewage from this source altogether; it is the more important, therefore, that the authorities deal effectively with the sewage from the stationary population which is under control.

Cleanness, a Commercial Necessity.—On the day I arrived in New York the newspapers referred to a remarkable speech by the Mayor on the subject of the growth of imports and exports at several harbors of the United States. The occasion for this speech was the 144th anniversary of the organization of the Chamber of Commerce, and it was shown that the increase of trade at New York was far and away greater than at any other port in the country.

Since 1898 the increase at the port of New York was	111 per cent.
“ “ “ “ “ “ “ “ Philadelphia “	75 per cent.
“ “ “ “ “ “ “ “ Boston “	17 per cent.
“ “ “ decrease “ “ “ “ Baltimore “	7 per cent.

All the facts and considerations of the case lead me to the conclusion that the community must bestir itself if it would retain for its harbor the good name which is now associated with it. Let the cases of Marseilles and Glasgow, be a warning. Many years ago the Clyde became so foul that even poor trippers declined to board pleasure steamers nearer to the Broomielaw than Greenock several miles down the river. Since that time large sums of money have been spent on sewage disposal works, but the bad reputation justly associated with the name of the Glasgow harbor years ago will not be got rid of for many years to come. Every port has a duty to every other port, which if faithfully observed, would inaugurate a state of things that would go far to lessen the duties of port, sanitary and quarantine officers.

23 Discussion of the Metropolitan Sewerage Commission's Four Schemes for the Purification of the Harbor.

What then is the most practicable, the most hygienic and the most permanently economical scheme to adopt? I have studied the vari-

ous schemes put forward in the admirable reports which you have sent to the Mayor of the City since September, 1911.*

* Metropolitan Sewerage Commission's Preliminary Reports on the Disposal of New York's Sewage, I to V inclusive.

Although the schemes enumerated in your reports may not have exhausted every phase of what you term the art of sewage purification, yet in my view you have considered every method applicable to New York which can be regarded as reasonably practicable.

Scheme 1 refers to the application of sewage to land. (Broad irrigation and intermittent filtration.)

Scheme 2 refers to filtration of sewage through biological filters (bacteria beds).

Scheme 3 refers to treatment of sewage by a variety of methods at various points of outfall, each case being adapted to its special circumstances, and the ultimate disposal of partially purified liquid into the nearest water course.

Scheme 4 refers to the conveyance of a large part of the sewage out to the Atlantic ocean with the minimum of treatment.

Scheme 1.

Application of the Sewage to Land.

The popularity of irrigation as a means of purifying sewage is on the wane, chiefly owing to the extensive area required and the unsuitability of the land available.

The Berlin farm, which is the largest in Europe, continues to do good work. The largest farm in England was at Birmingham, but some years ago when land could no longer be obtained for less than three times its agricultural value, the authorities abandoned irrigation in favor of the intensive method of purification on bacteria beds. The largest farm in France is at Paris, and there also the authorities contemplate a change of method whenever it is necessary to increase the purification plant.

Where all the conditions are favorable, irrigation is undoubtedly successful as a vehicle of purification, and one which generally yields consistently good effluents, but in New York the farm would be so colossal in extent that the conditions would not be invariably favorable. The available land is, I fear, limited to Long Island, the area required would exceed 150 square miles. It would necessarily vary in its adaptability for the purpose, and although the standard of purification need not be exceptionally high in view of the large volume of water into which it would ultimately be discharged, it would still be necessary to limit the volume of sewage to 10,000 or 12,000 gallons per acre, unless a great expenditure for under drainage were undertaken.

Sanitary Objections.—A great area of land lying between Amityville and Quogue overlies one of the sources of the city's present water supply, and its use for sewage purification would be a potential source of plague which no one would care to risk.

The mere saturation of 150 square miles of land with sewage would be a menace to the inhabitants obliged to reside in the district, and would be sure to produce mal-odors during certain states of the atmosphere, which would be highly objectionable, even if they did not markedly influence the health statistics of the district.

I disapprove of this method of purifying New York sewage on grounds quite apart from cost; nevertheless, it is important to note that it is the most costly of the schemes brought forward, and would probably amount to \$180,000,000; this, too, assumes that land could be acquired for about \$500 per acre—a somewhat sanguine estimate.

Scheme 2.

Oxidation in Bacteria Beds.

The epoch-making experiments of the Massachusetts State Board of Health have led to the adoption of what has been called the intensive method of purification. By this, biological filters are made to take the place of land, and in your case would probably purify 140 times as much sewage as the same area of land under irrigation. It is a method which is almost invariably adopted in modern works which are located some distance from sea, lake or river.

To carry the whole or the major portion of the New York sewage to Barren Island and then treat it on bacterial filters would be costly, and could only be justified if it could be shown that a specially good effluent is essential at the point of discharge.

As the oyster beds will probably depreciate in value as the population of the district increases, it would not be wise on this
25 account alone to incur the expense of this operation, more particularly as it is now admitted on all hands that the passage of sewage through a biological filter does not necessarily deprive it of pathogenic organisms, and in order to protect the oysters from the attack of a stray typhoid bacillus, it would in this case be necessary to sterilize before 1940 a quantity of sewage equal to about 700,000,000 gallons.

Danger of Nuisance.—Perhaps Barren Island is the very best site available for placing an installation of percolating filters, but it would appear as if Jamaica bay were on the eve of great developments, and that Barren Island would not for long be the isolated place it now is. I regard it as of the utmost importance to establish sewage purification works where they are not likely to become a nuisance, and I have grave doubts about the wisdom of placing so vast an area as 1,000 acres of bacteria beds so near to an industrial centre as they would be on Barren Island. In contemplating such a scheme there is a factor which should be taken into account, and that is the after effects of the evaporation of so much foul liquid as there must necessarily be from such an area of filters.

In 1911, when the summer weather in England was warmer than usual, there were complaints of smell nuisance at Henley, where the sewage is of about the same strength as the average American sewage, and where it is distributed over rectangular percolating beds by

mechanical distributors moving backwards and forwards. Complaints were also made by residents near the Birmingham works, where the sewage is sprayed over the beds by fixed nozzles.

The chief lesson to be learned from the 1911 experience is that an increase of flies is to be looked for in the neighborhood of bacteria beds in hot weather, and that objectional smell adjacent to them is more pronounced during prolonged hot weather than at other times. e. g., seasons like the average English summer, when the temperature rarely exceeds 65 Fahr. in the shade. But a much more serious drawback to a great area of bacteria beds during spells of prolonged hot weather is the formation of vaporous "clouds," due to the evaporation of sewage. These clouds appear to form over the beds in quiet weather. They rise to some distance above the earth, and at sundown, when the earth begins to cool, they return not alone as refreshing dew, but with offensive odor. If this occurred only in the vicinity of the bacteria beds, where the land is generally less valuable than at some distance, it would not be so serious in its consequences, but it generally occurs at some distance from the bacteria beds, the direction and distance depending upon the tendency and the velocity of the wind.

Cost.—Of course, it is only the mal-odorous element in sewage that makes this phenomenon noticeable; evaporation from clean water would act precisely in a similar manner, but it would manifest itself in welcome dew on the grass. This led me to adopt at Bir-

26 mingham the use of hypochlorite of calcium with excellent results, but the cost would be a serious matter where 700,000,000 gallons had to be treated each day; indeed, the bare probability of hypochlorite of either calcium or sodium (and the latter is even more effective) having to be used frequently, would be sufficient in itself to retard the adoption of a scheme which would be many times as large as anything now in existence. It is obvious that climate is of paramount importance.

The initial cost of 1,000 acres of biological filters to deal with 700,000,000 gallons of sewage, would be not less than \$140,000,000, apart from maintenance charges. Altogether, I agree that the commission would not be justified in espousing this scheme as the best available for New York.

Scheme 3.

Local Treatment Works and Outfalls.

It is probably not far from the truth to say that the only purification of organic matter known to nature is an oxidising one, which is brought about indirectly by the agency of bacteria, but whether the vehicle by which the process is brought to fruition is the irrigation farm, the biological filter or dilution with large volumes of clean water, the "combustion" process is practically the same.

To protect the harbor from pollution, it is neither essential to confine the purifying process to one method, nor to one locality, but whether it is expedient or wise to construct dozens of sewage purifica-

tion plants in and around New York is an entirely different matter. Sewage from the various districts delineated on the plans could be sufficiently treated to admit of being discharged in the adjacent waters without creating a nuisance, but in some cases the treatment would have to be very circumscribed, and a greater burden would be placed upon the assimilating powers of the waters than they ought to be called upon to bear.

Essential Details.—It is unnecessary for me to refer in detail to the various outfalls that would be required under this scheme. Suffice it is to say that I have examined many of the suggested sites, with the invariable result that they all appear to me to have been chosen with great judgment and engineering skill. It is more than probable, however, that if Scheme 3 finds most favor, the sites shown on the plans, and referred to in your reports, may have to be altered when negotiations for the purchase of those sites are begun; this will be found to be specially true in the case of the nineteen outfalls on Manhattan Island.

Under this scheme it would be necessary to lay sewers towards an outfall which would terminate in the deepest water available in the vicinity, where it would be dispersed by a complete system of moderate sized outlets so placed as to enter the stream transversely to the flow, and in sufficient number to encourage equal diffusion. Each outfall should be protected by grit chambers and settling basins in duplicate; the former should be provided with every appliance requisite to remove solids of large size, road grit, rags, etc.

Disposal of the Sludge.—The basins should be built so as to induce the sludge arrested by mechanical or chemical precipitation (as may be found best under circumstances which vary considerably at different outfalls) to collect at, say, the apex of an inverted cone or pyramid, and the sludge collected should be pumped daily into steamboats built for the purpose and removed well out to sea. This system of getting rid of sludge is well suited to a scheme which would have all its sludge tanks within easy reach of navigable water.

In my view the sludge should be removed daily so as to obviate smell nuisance. The only alternative would be to septicize the sludge in Emscher tanks, but this would mean large and deep tanks which would be incompatible with the conditions obtaining at some of the outfalls, particularly those in Manhattan, where the sludge tanks would perforce be placed in the streets abutting on the bulkhead and shore lines. The experience of the engineers at London, Glasgow and Manchester puts at rest any doubt as to the practicability of removing unsepticized sludge by steamboat, but there is nothing equally convincing to show that if it were in a state of active fermentation it could be so easily removed and so quickly lost to view when dropped into the ocean.

Only Limited Treatment Practicable at Wards Island.—If such a scheme as this were to be carried out, its weakness would probably become apparent first at Wards Island, where 302,000,000 gallons

of sewage will have to be treated daily in 1940. The reasons I have given against the establishment of a great area of filter beds at Barren Island are even more potent when applied to Wards Island, so that either mechanical or chemical precipitation would in the present state of knowledge have to be resorted to, and neither process is efficient enough to warrant me in suggesting that such a volume of effluent could be discharged into the East river without unduly drawing upon the oxygen of the harbor water.

One of the leading factors in considering the Wards Island problem is the fact that the river, so called, is without a continuous flow of fresh water towards the sea; any sewage effluent, therefore, would have to rely upon admixture with the water of a tide in order to obtain the necessary supply of oxygen to obviate putrefaction, and considering the volume available for this purpose, I am doubtful

whether the results would be acceptable at all seasons of the year. Of course the sedimentation process including screening and sludge removal to sea, or that process plus the addition of a coagulant to help mechanical precipitation, do not exhaust the great sources of power in nature, and it is quite possible that we may before many years are over realize the practicability of electrolysed sea water. Your laboratory experiments stimulate me with hope, but I cannot in the present state of my knowledge recommend them as a practical solution of the problem.

Under this scheme there would be many outlets, all of which would require to be equipped with screens, grit chambers, tanks, and some kind of treatment works, before the effluent could be discharged and left for the nearest water to complete its purification by assimilation.

Scheme 4.

Conveyance of a Large Part of the Sewage to Sea.

The distinctive feature of this scheme is the provision of subterranean channels, or great sewers, into which each part of the municipality embraced within a prescribed area would have the indisputable right to discharge sewage and trades wastes without let or hindrance, knowing that the sewage would be conveyed right out to the Atlantic ocean. Nothing in the nature of treatment beyond arresting solids that would otherwise obstruct the pumps would be undertaken en route.

One important feature of this scheme would be the formation of an island in the sea about three miles south of Coney Island. The formation of such an island is by no means unprecedented, but the idea of forming one some miles from land for the sole purpose of treating sewage is a novelty in the history of sewage purification.

Scheme 4 involves pumping the sewage, screening it, arresting a proportion of the suspended solids in sedimentation tanks to be constructed on the island, and thereafter leading it by a series of pipes into deep water to secure effectual diffusion.

Having the sewage tanks on the island would obviate the usual troublesome claims for compensation in respect of depreciation of

value of adjacent property. The island could be extended almost indefinitely as occasion for extension arose. Its position would be the best possible from which the superintendent of the works might observe the ebb and flow of the tide, and regulate the emptying of the sedimentation tanks.

29 The Treatment Necessary.—The question of the extent to which sedimentation should be carried is one which will gradually settle itself. I do not think it will be necessary to effect settlement until after the first section of the work has been in operation for some time, but as section after section is completed it will be found necessary to arrest the solids in tanks, made with the view of concentrating the sludge at the bottom of either conical or pyramidal pockets placed at an elevation to induce the sludge to flow by gravitation.

The precise site of the proposed island will require careful consideration, but that shown on your plan appears to be feasible. Excepting rip-rap for the external formation, nearly all the material for making it can be readily and cheaply obtained chiefly from (1) debris or spoil from building sites which at present is dumped into the ocean; (2) spoils from the tunnels and terminating shaft, and (3) sand pumped from the adjacent sand banks.

The Progressive Steps in this Scheme.—The first step to be taken if this scheme is entertained is to collect sewage from those parts of Manhattan and Brooklyn which border on the East river, convey it by tunnel to a central pumping station at Wallabout, near the Navy Yard, and lift it to another pumping station at Sheepshead bay, whence it would be conveyed to the projected island for disposal.

The population of the districts to be served at first by this instalment, and the dry weather flow of sewage pertaining thereto, are as follows:

District.	Population, 1915.	Sewage, Gallons per day.
Manhattan	680,000	99,000,000
Brooklyn	732,000	104,000,000
Total.....	1,412,000	203,000,000

The Wallabout pumping station would lift 133,000,000 gallons coming from the north, 18 feet in height, and 70,000,000 gallons from the south, 33 feet in height, and the Sheepshead bay station 203,000,000 gallons about 38 feet in height.

This instalment could be executed for about \$18,000,000, which would entail for interest (at 4½% for 50 years) together with maintenance charges, an annual payment of \$1,500,000, but I do not recommend you to limit the size of the tunnel to a carrying capacity of 400,000,000 gallons, or about twice the dry weather

30 flow, as I believe the second instalment of the scheme should be undertaken soon after the completion of the first.

The second instalment, I apprehend, would be to couple up the intercepting sewer which would serve the Jamaica Bay Division, shown on the plan accompanying your report to the Mayor, dated November, 1911.

The third instalment of the work should bring the sewage of the Upper East river and Harlem Division into the system, and the fourth would take in Richmond and as much of New Jersey as may be determined.

In my opinion all the intercepting sewers should be capable of conveying not less than twice the dry weather flow before storm water is shed into the nearest watercourse; this would correspond favorably with the English practice of conveying six times the dry weather flow,* or rather less than 200 gallons per head per day.

Need of a Permanent Sewage Disposal Commission.

Of the four projects thus briefly outlined as possible schemes for adoption, I have a decided preference for Scheme 4. I admit that Scheme 3 is feasible, but it lacks finality and possesses features which should be avoided when possible, e. g. the numerous outfalls and the drawbacks attaching to them in the eyes of the general public, their not invariably suitable locations, and their inevitable increase in number as the population increases. What influences me most in favor of Scheme 4 is the conviction that where it is possible to remove the bulk of the sewage of New York entirely away from its source to the ocean it should be so removed, although the cost may be somewhat higher than it would be under a project like Scheme 3.

In a great city where such public services as water supply, sewerage and sewage disposal are indispensable, and where several self-governing municipalities benefit by the common service, it is essential in the interests of good and economical administration that there should be a permanent commission, with jurisdiction over the whole area. Such a general commission from its very constitution is enabled to deal with questions more comprehensively than local boards, commissions, departments or bureaus can do. Probably an example of what I mean may be found by reference to the endeavor to improve the insanitary conditions of the Gowanus canal, where a local sewer

31 bureau tried to remedy a nuisance by conveying a stagnant, putrid liquid from one locality to another in the same neighborhood. No doubt the bureau did the only thing available to them at the time, but they were obviously restricted in their outlook, and were forced by circumstances to mitigate rather than remedy the evil, whereas if it had been possible for them to order the polluted waters of the canal to be conveyed beyond the municipal boundaries to the ocean, the evil would have been effectively remedied. A municipal engineer's work is often unfairly criticised because the effects of being hemmed in by surrounding boroughs is not adequately appreciated. Administrative questions, like sewerage, are not invariably united, but here they should be under one commission or board, and it is with the object of devising a workable scheme for keeping the harbor free from solid as well as liquid impurities that I suggest the formation of a commission to be entrusted with the duty

* For comparison between English and American sewage, See Preliminary Report VI, of the Metropolitan Sewerage Commission of New York, January, 1913.

of making and keeping pure (or reasonably pure) the national waters.

Proper Functions of a Permanent Commission.—The constitution of such a commission would have to be carefully framed by those who are well versed in existing statutes and inter-state law, but I venture to suggest one or two points which should be carefully embodied in the constitution.

The whole responsibility for maintaining clean waters within the prescribed area should rest upon the commission, and they should have all necessary power to enforce their regulations.

The commission should be responsible for the design of all intercepting sewers, pumping stations, tanks, outfalls, &c., essential for the construction of a complete installation of sewerage and sewage disposal works. The board should also be made responsible for the construction of these works, and for their subsequent maintenance.

Each borough or municipality must have the same right to connect to an intercepting sewer or sewers that they now have to discharge sewage into harbor, river or watercourse.

The commission should be charged with the duty of seeing that pollution, which must be inevitable until the intercepting sewers or subterranean tunnels are all built and connected to the ocean outfall, does not increase, even although it should be necessary to construct temporary works for the purpose.

The joint board or commission should have ample power to decide whether an intercepting sewer or any other work is required, and to allocate the cost of construction to the users. It should also have power to regulate by bye-laws, or otherwise, everything which pertains to the keeping clean of the harbors, rivers, canals or water-courses within the area for which it is responsible. If it is usual to give such commissions rating, borrowing or financial powers, the board should be so empowered.

In recommending the adoption of Scheme 4 it is not to be assumed that I advocate its complete execution at once. If I have succeeded in presenting the whole project correctly, it will be apparent to all that the dominating factor is and must continue to be the condition of what I have called the national waters. As it stands at present, the putrefactive liquid entering them increases daily; their power of oxidising foul liquid is practically stationary, and as every sewer is diverted to the Atlantic ocean by being coupled up to the system under scheme 4, their condition will improve. I do, however, advocate progressive, consistent advancement until the completion of the scheme be attained, which I hope will be not later than 1925.

Necessity for Immediate Action.

I cannot say too distinctly that there is need for immediate action. The nature and extent of the tunnel work bars haste and precludes all chance of redeeming lost opportunities; therefore no opportunities should be lost.

Generally, I am in sympathy with the plans you have prepared; particularly do I espouse what you call Project 1 as the first step to

be taken. There should however be a comprehensive plan matured if possible in conjunction with the engineers of the several sewer bureaus, which will indicate how every link of the complete scheme will be caught up in regular progressive stages. This is the more important as there might be more or less prolonged intervals between each successive stage.

It will probably cost not less than \$100,000,000 to complete Scheme 4, undoubtedly the largest sum ever contemplated for such a purpose, but no scheme has hitherto been designed for the service of 12,000,000 people. Many small towns have spent more per capita than this estimate implies, and frequently all they gained was the removal of a liquid which possessed potential elements of plague. The citizens by approving the conveyance of all the sewage to the Atlantic will gain that and more, for they will at once purify their harbor and rivers, which never will cease to be the most priceless and most striking physical characteristic of New York.

Comparison with European Undertakings.—If one were to attempt a comparison between the cost of the sewerage systems of European capitals, and what is now proposed for New York, the great disparity between the quantities of potable water used by the inhabitants of cities of the Eastern and Western Hemispheres would arrest attention. The world has been startled by the magnitude of your water schemes. Any European city would have regarded 114 gallons per capita as an extravagant allowance, yet this—which is equal to a daily supply of 500,000,000 gallons—is what is now obtained from the Croton works alone, but rather than curtail that supply, or do anything which might be interpreted to favor a limited use of water for public health purposes, the authorities determined to carry out a gigantic scheme to obtain another 500,000,000 gallons of water per day, this time from the Catskill mountains. The magnitude of the undertaking, and the aggregate cost of bringing in 1,000,000,000 gallons per day will place the New York water supply in a category by itself when a history of the world's great water works comes to be written.

The consumption of water has a direct relationship to a city's sewerage system as regards cost, and it is incumbent upon an engineer in recommending a scheme to satisfy himself that it is not only sound as an engineering proposition, but that it is financially possible. The facts I have brought to your recollection go a long way to show that a scheme of sewage disposal which will ultimately cost \$100,000,000 and involve an annual outlay of \$5,000,000 for the benefit of 12,000,000 people is not disproportionate to the requirements of the city. But I have not relied alone upon the example of the water works in coming to this decision. The numerous public schools, seats of learning, public institutions, colossal buildings, wide streets, stupendous bridges of unparalleled width, not to speak of railroad, canal and private enterprise, the most recent examples of which may be found in the Pennsylvania and Grand Central stations, which between them have cost not less than \$300,000,000, all direct one's attention to indisputable evidence of prosperity and progress, and to what is of even more importance, the attitude of mind which

shows that the people have a profound faith in the future greatness of their marvellous city.

It is quite unnecessary to caution you that all estimates of cost, so far as they have been prepared by me, must be regarded as of a tentative character, and should be accepted cautiously until complete surveys, detailed plans and sections are made, and schedules of quantities drawn up—nevertheless they seem to me to be quite ample for the work contemplated.

I am, gentlemen, your obedient servant,

JOHN D. WATSON.

Birmingham, 31st January, 1913.

a COMPLAINTANTS' EXHIBIT No. 204. James D. Maher, Commissioner.

Report of Observations of Sewage Disposal Works in Hamburg, Dresden, and Frankfurt, Germany, by Samuel A. Greeley, Sanitary Engineer, September, 1911.

1 **Hamburg.**

August 30th and 31st—September 1st.

Description.—Hamburg is a city of about one million inhabitants in Germany, on the River Elbe. The river divides the town into a larger northern section of about 850,000 people, and a smaller southern section of about 150,000 people. Near the center of the northern district is a large lake or basin, called the Alster; and there are several small streams and canals throughout the city. The southern section is chiefly a manufacturing and shipping center, and is all cut up with slips, harbors and docks. The city is a large shipping center and there is a continuous passage of ships of all kinds back and forth on the river. The whole city is sewered on the combined system, and there are numerous overflows for storm water at various points throughout the city, on the Alster and the smaller streams and canals. These overflows are arranged so that no discharge takes place directly into the water courses until the normal dry weather flow has been diluted with rain water in the proportions indicated in the following table for the various classes of water courses:

Volumes of Dry-weather Flow and Rain Water in the Combined Sewage at Time of Overflow.

Kind of water course.	Volume of dry weather flow.	Volume of rain water.
Elbe River	1	1
Lower Alster	1	3-1/2
Upper Alster	1	5
Small streams & canals	1	10

2 This information was given to me by Herr Brunotte, engineer in charge of sewage disposal. Previous to the time of my visit and while I was in Hamburg, these storm overflows had not been used for at least six or seven weeks.

The sewage of the northern district is all conducted to one main point of discharge into the Elbe river. The sewers leading to this point of discharge are large, smoothly built, well ventilated, and have good slopes, so that the sewage reaches the point of discharge in a fresh condition, without much odor. Herr Brunotte told me that the minimum velocity of flow in the system was 0.6 meters (1.97 ft.) per second, but that this minimum was confined to a few small

sewers and that in the main trunk sewers the velocity of flow was about 1.0 meters (3.28 ft.) per second. He estimated that the time of flow for most of the sewage coming to the northern district point of discharge was from two to four hours, depending upon the volume of sewage flowing in the sewers.

The sewage from the southern district will eventually be concentrated at one point of discharge. At the present time, the sewage from only about one-third of the population of this district is so concentrated, the remainder flowing directly into the Elbe through various dikes and canals.

With regard to the preliminary treatment of trades wastes, there are certain rules, which Herr Brunotte summarized as follows:

- (1) Factories must first neutralize their waste liquors.
- (2) Oil, fat, etc., must be held back by a scum board.
- (3) Asbestos works and some other special works must have settling basins.

3 Herr Brunotte told me that these rules were not enforced to affect over 25% of the trades waste; and in talking with Herr Helmke (an assistant engineer who went to the disposal works with me), I gathered that this statement was rather optimistic than otherwise.

The Elbe river, as it flows through Hamburg, is a tidal stream, (See accompanying tables of high and low tide at Hamburg, Appendix II.) the water being yellow-colored and turbid, with a fine "mucky" sort of suspended matter. Above the town it is used for the city water supply and is not strongly colored or turbid, but requires filtration to make it a clear, safe drinking water. The intensity of the tide is about 3 meters (9.8 ft.), but the stage of the water at Hamburg varies with the wind, being highest after a long continued west wind which piles the water up stream. I asked everywhere for some data relative to the Elbe watershed above Hamburg, but could find none. Herr Brunotte quoted to me the average flow of the Elbe at Hamburg as being 1125 cbm. per second (25,677,324,000 gal. per 24 hrs.), with a minimum of 156 cbm. per second (3,423,643,200 gal. per 24 hrs.), to be expected once every twenty or thirty years. Herr Brunotte's authority for this statement was a book entitled

"Hamburg in Naturwissenschaftlicher und Medizinischer Beziehung."

(Sonder-Abdruck.)

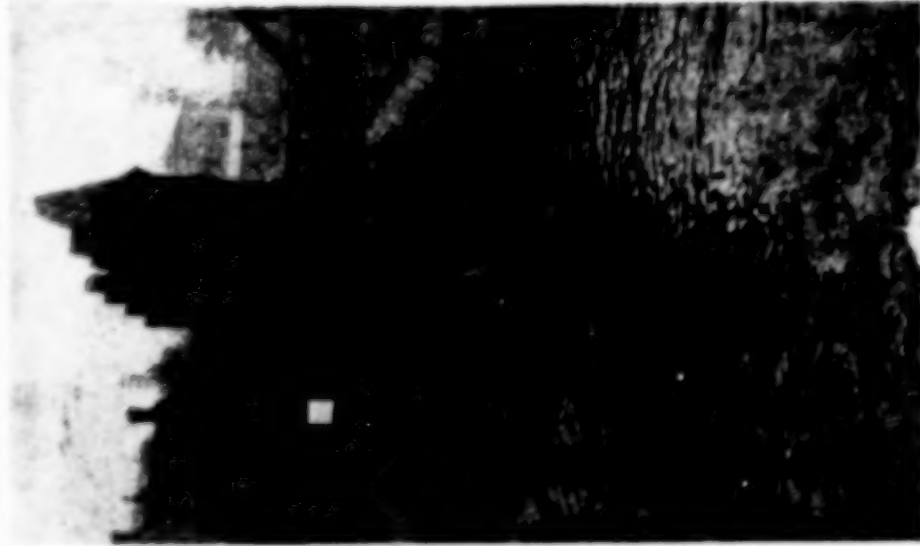
Hamburg.

Verlag von Leopold Voß.

1901.

4

This can be purchased from Boysen and Marsch, Heuberg, Hamburg, for 15 marks (\$3.75).

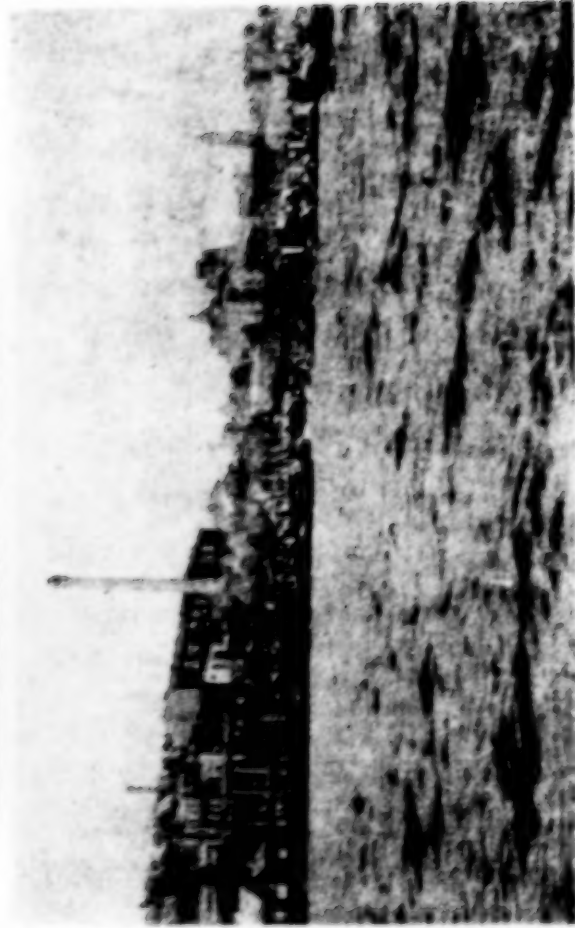


Nº 1.

Hamburg screening plant,
Northern district.

Tower through which sludge
and screenings are dis-
charged into the tank boats.
Tank boats shown below.

(Exhibit No 204)



Photograph of sea-gulls over outlet of the Hamburg
screening plant (northern district). Note the
density of the buildings.

Nº 2

--4--

At the time of my visit, the quantity of water flowing in the Elbe must have been very low, because this summer has been one of the driest in Germany for many years. I was unable to secure accurate data on this point, but was told that by writing to the Strom and Hafen Bau Abteilung, Dahlman Str., Hamburg, in an official way, the data could be secured. However, I found at Dresden that the Elbe was at its lowest stage this summer, and throughout my travels everyone spoke of the extreme drought in Germany. Herr Brunotte stated that the filtered Elbe water was not unusually hard and was used for many boilers without preliminary treatment. The immense number of ships and tugs passing continuously back and forth on the Elbe keep the surface water churned up so that it is always choppy and there is little opportunity to observe sleek on the surface.

The Disposal Works.—Both northern and southern districts are equipped with disposal works. These consist of (1) coarse bar screens at the end of the main sewer; (2) small grit chambers, and (3) revolving mechanical screens of the belt type.

The old plant, serving the northern district, is located on the river front in a very busy, thickly built up section of the city. The environment is undoubtedly critical. (See photographs Nos. 1 and 2.) Within about four blocks is the seaman's school and the entrance to the new tunnel under the river. (See map of Hamburg, marked Appendix IV.)

(Here follow photos marked Nos. 1 and 2.)

5 This plant has one grit chamber, containing two screens. The bars of these screens are spaced 15 millimeters (0.59 inches) in the clear, and the screens are each 3.3 meters (10.8 ft.) wide. The screens travel at the rate of about 2 meters (6.56 ft.) per minute, and have only one speed of operation. They operate only at low tide because at high tide the river water is higher than the sewer water. There is a period of from 1 to 5 hours, averaging over 1 hour, when there is no discharge and the sewage is allowed to back up into the sewers. The river is highest when a heavy west wind drives the sea water up stream, and this reaches a maximum when it is combined with a heavy rain. Under these conditions, which I was told happened during the spring of 1911, the period of discharge lasts only for about one hour. (See descriptive illustrated pamphlets of Hamburg's sewers and screening plants—marked Appendix III A and B.)

The average quantity of sewage flowing through this plant is 190,000 cbm. (50,192,300 gals.) per 24 hours. It flows through the grit chamber at a velocity varying from 0.8 (2.62 ft.) to 1.2 meters (3.94 ft.) per second.

The grit chamber is cleaned two or three times a week, the cleanings amounting to from 12 (15.7 cu. yds.) to 16 cbms. (20.9 cu. yds.) daily. The screens, which are cleaned continuously during operation, remove from 10 (13.0 cu. yds.) to 50 cbms. (65.4 cu. yds.) daily, the average removal being 20 cbms (26.1 cu. yds.) per day of wet screenings. The sludge and screenings are dumped into covered steel barges which are towed to the dumping grounds, several miles below the city.

6 After the sewage passes through the screens, there are five discharge pipes through which it may pass into the river. Ordinarily only three of these are used, the other two, which extend only to the water's edge, being used during times of storm flow only. The other three pipes extend into the river 70 meters (229.6 ft.), 100 meters (328.0 ft.) and 133 meters (436.2 ft.) from shore respectively, and all are turned up 90° at the end and discharge at the bottom of the river.

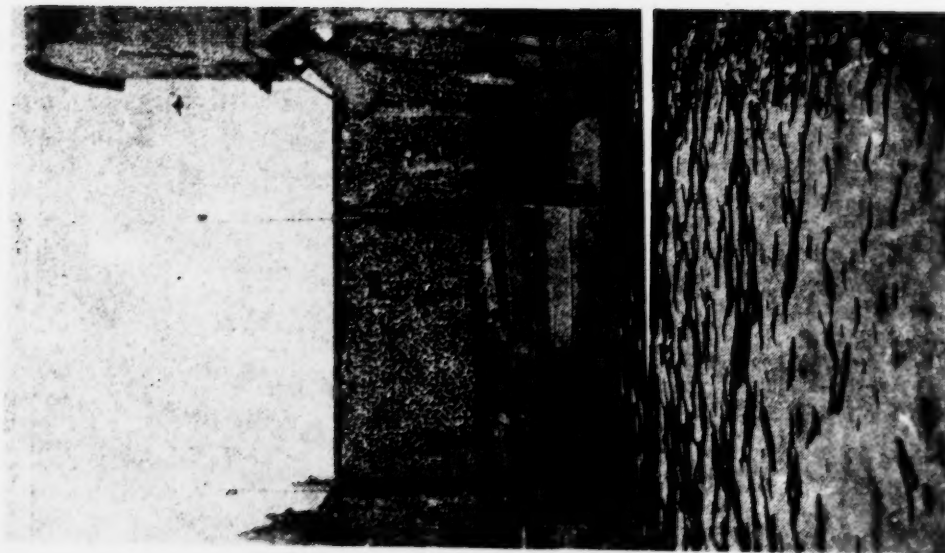
The new plant is located at the end of the Kaiser Wilhelmshafen, and is attractively built of red brick, with well kept up grounds. It is in the heart of a busy shipping neighborhood, in the close proximity of many commercial buildings. (See map of Hamburg, marked Appendix IV.)

The plant consists of two grit chambers, each fitted with two screens; and there are pumps to lift the screened sewage into the river. At the present time the pumps are not connected, and the effluent from the works discharges about midway between high and low tide and at the shore just south of the Reiherstrasse Bruecke.

The grit chamber and screens are very similar to those at the old plant. The important differences are, (1) that the bars of the screen are spaced only 19 millimeters (0.39 inches) in the clear; (2) that the velocity of the sewage striking the screens is less, and (3) that the screens travel more slowly.

The plant is operating below capacity, only about 6,000 cbms.

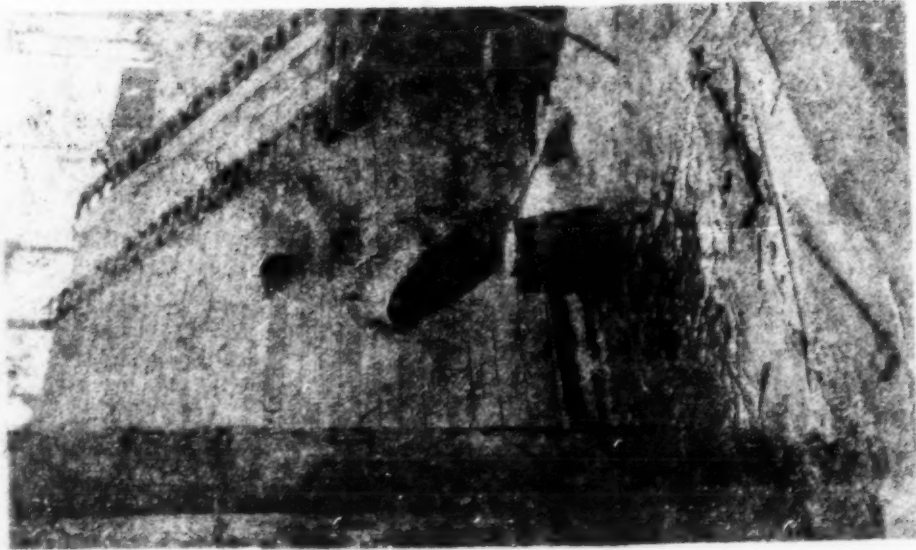
(Exhibit No. 3)



No. 3.

Hamburg Screening Plant, Southern District,
Sludge Tower and Tank Boats.

(Exhibit No 204)

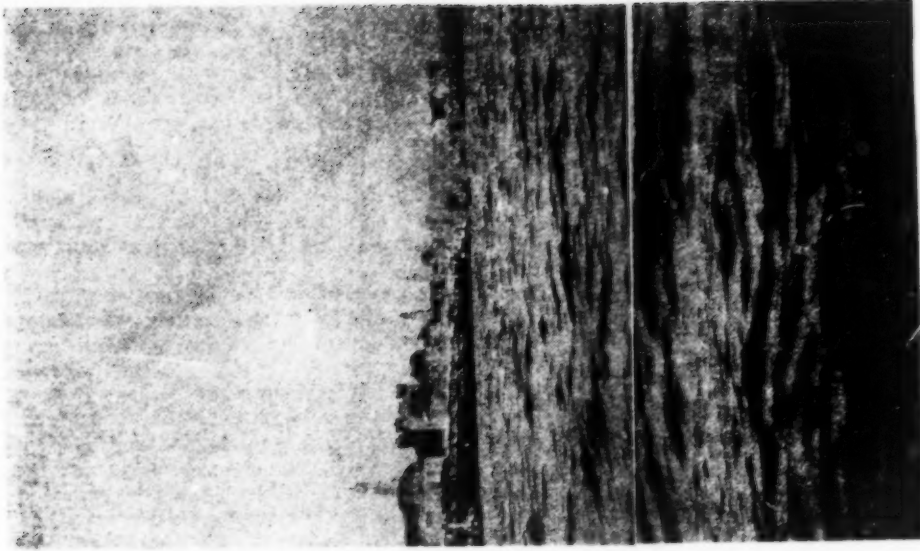


No. 4.

Hamburg Screening Plant,
Southern District;

Discharge of Effluent.

(Exhibit No 204)



No. 5.

Hamburg Screening Plant,
Northern District,

Approaching the old plant.
Note gulls over the water.



7 (1,585,020 gals.) daily of sewage being handled. The grit chamber is cleaned once a week, when about 60 cbms. (78.5 cu. yds.) of sludge are removed.

Work done—Aug. 30.—In the morning I called on Herr Brunotte and talked with him about a half-hour. I returned to Herr Brunotte's office at 1:30 P. M. and met Ing. Helmke, who took me to the new plant and from there by boat to the old plant. This trip took the whole afternoon.

Aug. 31.—About 9:30 A. M. I reached the old plant, to observe the conditions while there was no discharge of sewage. Then I went in a launch down the river, to see where the sludge was handled and, coming back, took samples of Elbe water for observation. This took all day.

Sept. 1.—In the morning I called on Herr Brunotte again and talked with him for about one hour. Later I called on Ing. Heinrich Luhr, who is now in the water bureau, and questioned him with reference to the water supply.

General conditions during visit.—The summer of 1911 in Germany has been a very dry one, one of the driest in twenty or thirty years. Previous to my visit, it had not rained for six or seven weeks, and during my visit there were only one or two short, light showers, that left no apparent effect on the pavements and affected the sewage flow but little. For the rest, the weather was clear, with a fresh breeze blowing most of the time.

8 Visits made Aug. 30.—Ing. Helmke and I left Herr Brunotte's office about 1:30 P. M. and proceeded by trolley, ferry and on foot to the new screening plant on the south side of the Elbe. The general appearance of the plant, as we approached it, was attractive and no sewage odor was noticeable until we had entered the grounds. They were trying out some sprinkling filters which smelled a little, but the strongest odor noticeable was from the tower used to discharge the sludge and screenings into the tank boat. (See photograph No. 3.) We passed this on our way to the pump house and screen room. It could not have been called objectionable, but the wind was blowing the odor away from me.

(Here follow photos marked No. 3, No. 4 and No. 5, pages 9 and 10.)

11 Inside the screen house there were evidences that the plant was not having sufficient sewage delivered to it. The screens were not operating and the sewage was flowing through very listlessly. The sewage was black and greasy in appearance and there was evidently much oil in it. They started the screens for me and also lifted a bucket full of sludge for me. This action liberated a lot of gas bubbles in the sludge, and they bubbled up through the heavy liquid but did not smell strongly. After observing the screens and grit chamber, we went to the tower through which the screenings and sludge are shot into the tank boat about 20 feet below. This tower was not very well cleaned and when I stepped into it, I could get the strong pig-pen odor easily, though the wind was blowing briskly.

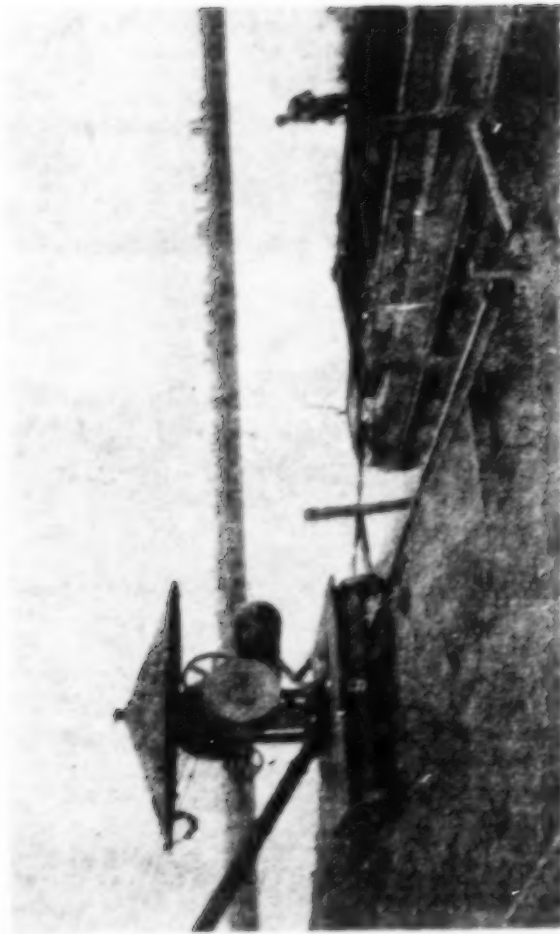
We then took the city launch and went to the outfall of the effluent from this plant. This is shown in the accompanying photograph No. 4. This was about a 30 inch sewer, discharging at the shore and about 5 feet above the water level at the time of my visit. There was a barge anchored directly below this outlet and some carpenters were doing some repair work on the barge. There was no serious nuisance at this outlet. The sewer was only flowing about 3 inches full.

From here we went by the city launch to the old plant, and on the way there was good opportunity to observe the Elbe water. (See photograph No. 4.) This was in all places a yellowish brown, without many large floating matters. The river was very choppy (and they say always is), so that there was very little opportunity for sleek to collect on the surface. Here and there, I saw a few blotches of it, say about 12 inches in diameter. As we came within 12 100 yards of the plant, there was a slightly noticeable sewage odor (I found out afterwards that this probably came from the sludge boat).

The buildings and grounds of this plant were also attractive. Entering the screen room there was, of course, a sewage odor, but this was not noticeable outside the plant. The sewage appeared fresh (fresher than at the south district plant) and did not smell strongly. The depth of sewage in the grit chamber, I measured to be 3 meters (9.8 ft.). It was flowing through at a good velocity (much faster than at the new plant). I timed the screens to be traveling at about the rate of 30 cm. (11.8 inches) in 8 seconds. After this we went to the tower through which the screenings are discharged into the barge. Here again was the strong pig-pen odor.

After visiting the plant, we went in the city launch to just over the outlets. Ing. Helmke pointed out the general location to me by some small floating matters and a white foam or froth on the water surface. There were sea-gulls flying about this part of the river, although I had seen them nowhere else. On the day of my visit, it was cool and there was a good breeze blowing from just west of north. The river was very choppy. I could not see any marked evidences that sewage was being discharged into the river, except the gulls. That is, the water was not discolored and there was no marked sewage odor from the river water at the outlets.

(Exhibit No.
204)



No. 6.
Hamburg Screening Plants
Tank Boat at Point of Disposal of Screenings.

(Exhibit No.
204)



No. 7.
Hamburg Screening Plants
Derrick and Dump for Sludge and Screenings.



The only strong odor came from the sludge and screenings. The evidences of sewage discharge were the slight clusters of white froth and the few floating particles.

13 Visits made Aug. 31.—I went first to the old plant, arriving there about 9:50 A. M. The outlet gates were closed and the sewage was standing in the grit chamber. I was told that this had been so for about half-an-hour. The depth of sewage on the fixed gauge was 4.57 meters (14.9 ft.) or 1.57 meters (5.1 ft.) higher than yesterday afternoon.

The day engineer at the plant told me this morning that, during stormy weather, the gulls flocked thickly over the sewer outlets.

The sewage in the grit chamber was bubbling somewhat, but the odor was not objectionable. The temperature of the sewage in front of the screens was 20.5° C. (68.9° F.).

At 10:10 I took a launch with an English speaking engineer and went to Newenfelde, where the screenings from the plants are disposed of.

(Here follow photos marked Nos. 6 and 7, page 14.)

15 We reached Newenfelde about noon and had a two mile walk to the small unloading station where the tank boats from the sewage plants are unloaded. The country we walked through was wholly devoted to truck gardens and orchards, and the whole neighborhood smelled of the pig-pen odor from the sewage screenings used as fertilizer. We saw it lying on the fields.

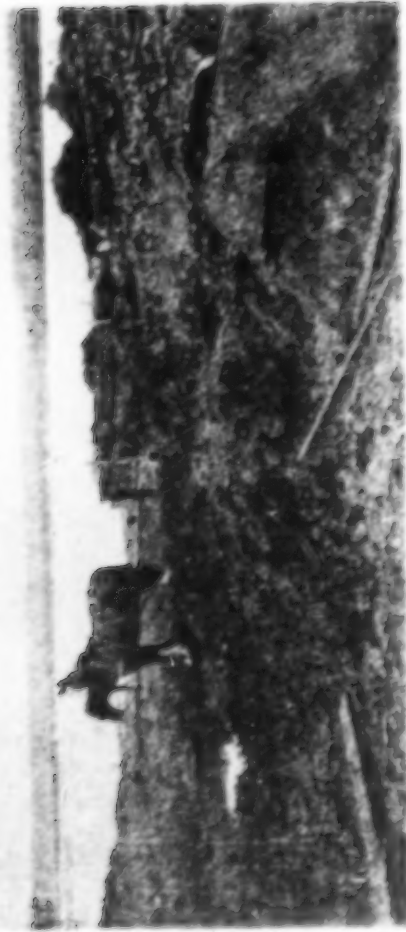
The unloading station is located on a small creek and was very foul. It consists of only an inlet for docking the tank boat, a derrick, some trucks and a narrow-gauge, movable track. (See photographs Nos. 6, 7 and 8.) The derrick is used to lift the body of the truck from the frame to the boat. There it is filled with a shovel and then replaced on its frame, and the whole car is then run out onto the dump. This dump was about 5 feet deep and 75 ft. by 50 ft. in area, and was very foul. The farmers come and cart this material away, paying 1 M. and 20 pf. per cbm. (22.3 cents per cu. yd.).

Coming back in the launch, I took especial notice of the well-kept beaches along the Elbe, where there were sailing boats and small row boats for hire. Here and there were bathing places. These were located within two miles of the sewer outlet and down stream. (See map and photograph No. 9.) The shore below the outlet did not show evidences of serious pollution.

On the way back, I took samples of the Elbe water at approximately the points marked on the map. The samples were taken by dipping the bottle, on the end of a string, into the river and taking the first bottle full as a sample. I took the temperature at points marked (1) and (4) and in both instances it was 19° C. (66.2° F.).

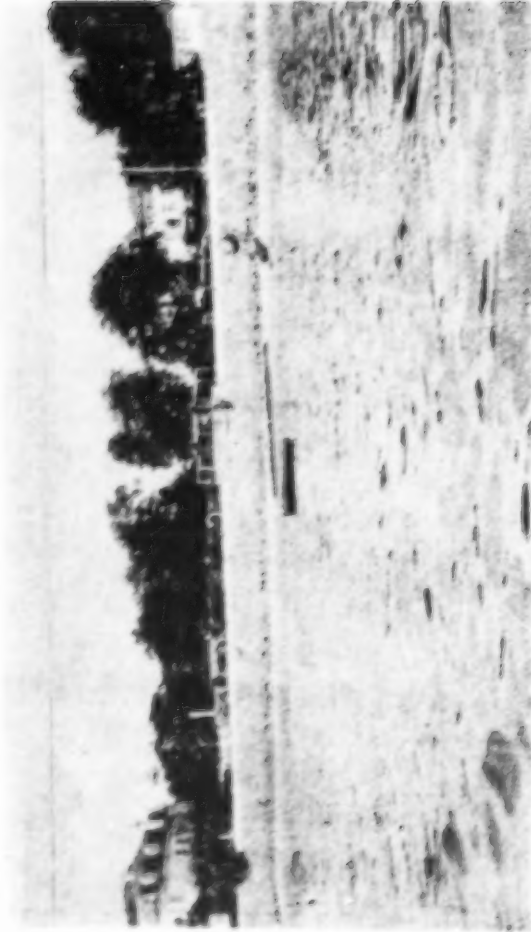
Here follow photos marked Nos. 8, 9 and 10, pages 16 and 17.)

(Exhibit No
204)



No. 8.
Hamburg Screening Plants
Farm wagon carting away sludge and screenings from dump.

(Exhibit No
204)



No. 9.
Bathing Beach about three miles
below Hamburg sewage outlet (old plant)

18 As we returned, there were gulls flying over the outlet.

I photographed these, as shown.

Description of samples of Elbe water.—On the trip back on the launch, I took six samples of Elbe water at the points marked on the accompanying map. The samples were taken about six inches below the surface, and were secured by dipping the bottle on the end of a string, the first bottle full being taken. These six samples I took back to my room and photographed them, as shown on the accompanying photograph No. 10.

All the samples were colored a yellowish brown, which did not increase on standing twenty-four hours. In each of them there was a fine "mucky" sediment. I tried the relative turbidity of the samples by the clearness with which I could see the lines of a sheet of paper (similar to the attached sheet) when looking vertically through the water. The bottles were about 5 inches deep.

Bottle No. 2 showed the greatest turbidity. The lines of the paper were just visible when observed near a window one hour before sunset, with no direct sunlight, on, a perfectly clear day. Samples Nos. 1, 4 and 5 were next in degree of turbidity. Then came No. 6, with No. 3 the clearest. There was very little to choose between Nos. 1, 3, 4, 5 and 6, No. 2 being distinctly darker than the others.

All the samples had a slight salty, fishy odor, which did not increase perceptibly after twenty-four hours. There was a fine sediment in the bottom of each bottle, and there was much
19 finely divided suspended matter throughout the water. The yellow color was the greatest mark.

The accompanying photograph (No. 10) shows the six bottles with a glass of clear water in the center. Sample No. 2 is the second bottle from the right of the picture.

I was unable to obtain any analyses or observations of the micro-organisms in the Elbe water. However, I secured a book entitled as follows:

Hamburgische Elbe-Untersuchung.

I.

Allgemeines über Die Biologischen Verhältnisse der Elbe bei Hamburg und über die Einwirkung der Sielwässer auf die Organism des Stromes.

Von Richard Volk.

1903.

This book gives data on both the chemical and biological contents of the river water. It is attached as Appendix V.

Summary of Observations.—1. That the discharge of the effluent from the sewage screening plants of Hamburg into the Elbe did not add seriously to the turbid appearance of the water, the Elbe itself being a colored turbid water at that point.



20 2. That the absence of a discernable sewage field was due to the dispersing of the sewage in the water through the agency of the ships, tugs and tides which intersect the water at many angles and keep the water continuously churned up.

3. That there were evidences of sewage pollution, such as the presence of gulls, the sleek near the docks and the floating particles.

4. That the greatest nuisance from the plants came from the handling of the sludge and screenings at the plant and from their ultimate disposal on land.

21

Dresden.

September 2nd.

Description.—Dresden is a city of about 550,000 people, situated on the River Elbe in the central eastern section of Germany. The river divides the city into a larger southern district called "The Old Town" and a smaller northern district called "The New Town." There are no other important streams or canals flowing through the town, and the sewage from both districts flows to one main disposal station below the city and then into the Elbe. At this disposal station, the sewage is screened before entering the river.

Unlike Hamburg, Dresden is not a great shipping center, but has what one might call "an average" population. That is, there is no great preponderance of any one class of population. The trades wastes do not form as important a part of the sewage as at Hamburg.

The Elbe river, as it flows through Dresden, is a fresh water stream, dark in appearance, with a velocity (as I observed it) of less than four miles an hour. At the time of my visit, the surface was smooth and there was some sleek evident on the surface near the shore even above the sewer outlet. The river is not used greatly for shipping, but there are a good many small river steamers and barges anchored along the bank (during my visit the water was too low for many of them). There are several bathing houses along the river, showing that the water is used for bathing, but the water supply for the town is taken from springs and wells, and not from the river.

(See map, Appendix VI.)

22 The quantity of water flowing in the Elbe and the quantity of sewage reaching the disposal works were given to me by Dr. Neidner, with whom I talked at the city hall, as follows:

Elbe:

Minimum flow—50 cbms. per sec. (1,141,214,800 gal. per day).

Normal flow—100-300 cbms. per sec. (2,282,428,800—6,847,268,400 gal. per day).

Maximum flow—6,000 cbms. per sec. (136,945,728,000 gal. per day).

Dry-weather sewage:

A daily average flow of 100,000 cbms. (26,417,000 gal.)

A daily variation of from 500 to 2,000 litres per sec. (11,412,144 to 45,648,576 gal. per day), the maximum occurring between 11 A. M. and 14 P. M.

Storm sewage:

A maximum of 18,000 litres per sec. (410,837,184 gal. per day). This exceeds the capacity of the four screens and part of the flow is by-passed directly into the river.

During my visit the river water was flowing at the minimum rate of 50 cbms. per second (1,141,214,800 gal. per day) and the sewage was about 1/25 of the river water. These are extreme conditions.

Dresden is sewerod on the combined plan. There are two main intercepting sewers—one on each side of the river. These flow down stream with an approximate slope of 1 to 3000, and the flow in them is rapid. The superintendent at the screening plant (who speaks English quite easily) told me that the time of flow of sewage from the center of town to the disposal plant was only about one-half hour, and the time of flow for most of the sewage did not exceed 2¼ hours from the point of entrance into the answer to the disposal plant.

23 The disposal plant, where the sewage is screened, is located well below the town in open country, on a large tract of farm land owned by the city. It is located on the north side of the Elbe. The sewage from the southern district passes under the Elbe in a siphon near the west end of the city. Just in front of this siphon is a grit chamber. The sewage from the north district comes direct to the plant, but passes through a grit chamber just before reaching the disposal plant.

The Disposal Works.—The two main sewers, after passing through the two grit chambers, come together near the disposal works, where the sewage is treated before flowing into the river. (See descriptive pamphlet, marked Appendix VII.)

The disposal works consist of

1. An office building.
2. A house in which are located coarse bar screens and scum boards.
3. A main screen house in which are located four of the large disc type screens.
4. A pumping station.
5. A house for the workmen.
6. By-pass conduits for the rain water.

The buildings housing the apparatus, offices, etc., are all large and attractive. The rooms are high, the areas are ample and the yards are large and well paved. The city owns a large tract of land about the works, but does not now use it for farming purposes.

24 There are no buildings within half a mile of the plant, and the location is not at all critical.

It should be stated that, except the two grit chambers, there is no opportunity for sedimentation of the sewage at the plant. The velocity of the sewage flowing through the works is rapid, so that few deposits are made.

In the preliminary screen house the coarse bar screens are arranged in duplicate, each side having three tiers or sets of screens. The spacing of these screens, beginning at the bottom, is approximately 2", 4" and 6" respectively. They all slope at about 60° with the horizontal, and each tier is provided with an accessible platform from which a workman rakes the screen clean. It is sometimes necessary to clean these screens once every thirty minutes. But generally once every four hours is sufficient.

The main revolving, mechanically cleaned screens are of the "Riensch" disc type and are 8 meters (26.24 ft.) in diameter. They are described in the accompanying pamphlet. As shown, these screens are revolving discs of perforated brass plates, fitting around the lower circumference of a truncated cone of brass plates. Each of these screens has a total open area of 14 sq. meters (16.74 sq. yds.). They revolve at two speeds, e. g.—1 revolution per 2 minutes and 1 revolution per 3 minutes. They are run generally at the lower speed. The slits through which the sewage passes are 2 mm. (.078 inches) wide on top, 3 mm. (.117 inches) wide on the bottom and 30 mm. (1.17 inches) long. The brass plates are 5 mm. (.196 inches) thick on the disc and 4 mm. (.157 inches) on the cone.

25 Each screen has a normal capacity of 650 gallons per second (56,160,000 gal. per day), and in dry weather one screen handles the whole flow. Maximum flow requires the operation of all of the four screens.

The maximum loss of head in going through a screen is 60 cm. (23.6 inches), and when this is reached, either the speed of the screen is increased or another screen is cut in.

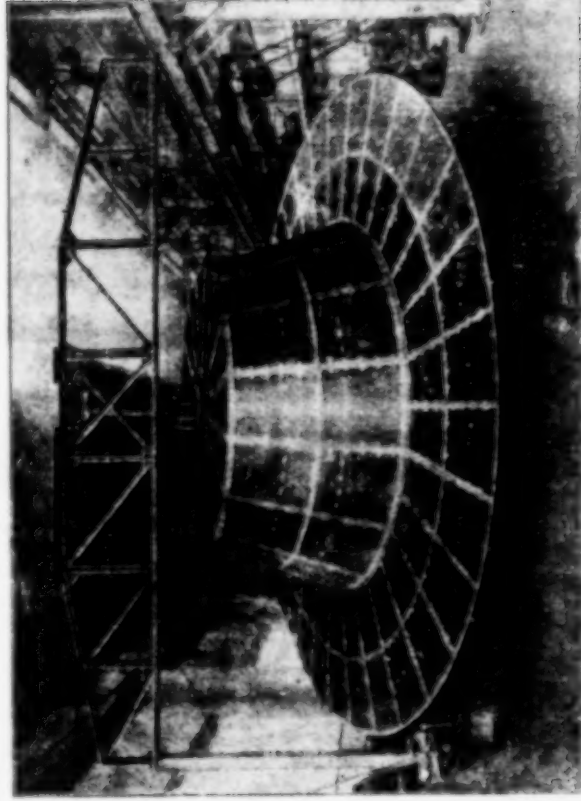
The screens are cleaned by revolving brushes, which scour the screenings off the screen into a conveyor, which discharges them into small cars in which they are conveyed to the dumps in the yard.

Each screen requires 2½ to 3 h. p. for its operation. (See Plate I for pictures and drawings of the screen.)

(Here follows diagram marked figure 23, page 26.)

Definitive Anlage Dresden

Weiterhin führe ich noch einige Photographien von Scheiben an, die augenblicklich in meiner Werkstatt ihrer Vollendung entgegensehen. Von diesen Scheiben dürfte die definitive Ausführung für die Stadt Dresden wegen ihrer ausgedehnten Dimensionen von besonderem Interesse sein. Wie aus dem in Figur 24 angegebenen Aufriß und



(Abbildung ke
204)

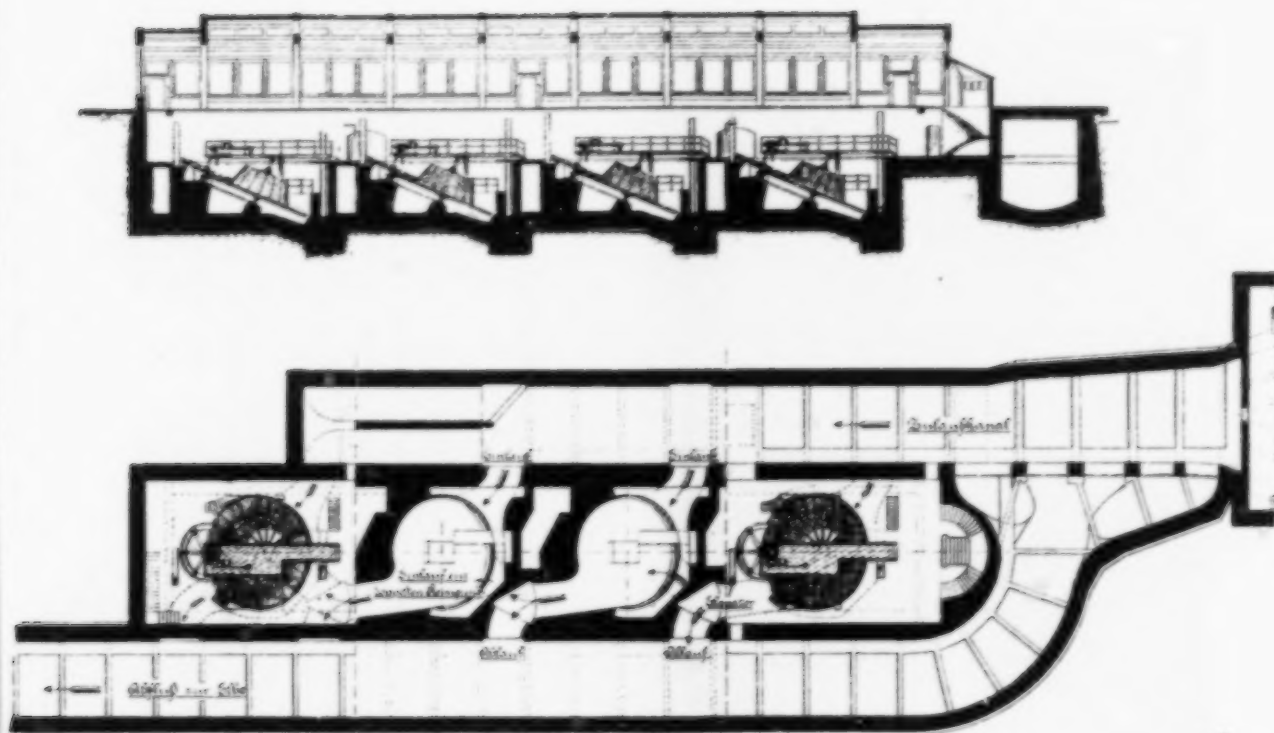
Figur 23.

Anlage Dresden in Werkstatt montiert, 8 m Durchm.

Grundriß der Kläranlage zu ersehen ist, sind für die Dresdener Ausführung zunächst 4 Scheiben von je 8 m Durchmesser vorgesehen, die zusammen im Maximalfall 18000 Sekundentlicher Schmutzwasser bewältigen. Die Scheiben sind mit gefrästen Bronzeflecken von 2 mm Schlitzweite versehen und so in den Abflußkanal eingebaut, daß sie einen Wasserstand von 2,4 m beherrschen. Einzelheiten der Scheibe sind aus der obstehenden Figur 23 ersichtlich. Die gesamten Abwässer Dresdens durchfließen diese Reinigungsanlage und laufen alsdann ohne weitere Reinigung der Elbe zu. Bei Hochwasser werden sie nach Passieren der Separatorscheibe in die Elbe übergepumpt.

Plate I.

Screening Plant at Dresden.



Figur 24 Anlage Dresden, 4 Scheiben je 8 m Durchm.

Ex. 204

27 The pumping station is used only during times of high water in the river. It consists of nine electrically driven, two-stage centrifugal pumps, having a combined capacity of 2250 horse power.

The total cost of the disposal works without land, but including the pumping station, was two and a quarter million marks (\$562,500.00).

Work Done.—I spent two days in Dresden—Saturday and Sunday, Sept. 2nd and 3rd. Saturday morning I called on Dr. Ing. Neidner in the city hall, and in the afternoon visited the sewage works, where I was shown around by Ludwig Scheitzow, the superintendent of the plant. Mr. Scheitzow spoke very good English.

General Conditions During Visit.—The two days that I spent at Dresden were both hot, clear, sunny days, with the thermometer at about 80° F. There was no rain on either day, and there had been almost no rainfall for several weeks previous. The Elbe was at its minimum stage.

Visit to Disposal Works—Sept. 2nd.—I went to the sewage disposal works by trolley along the south side of the river as far as Mohn street. From there I walked along the river, then through a suburb, and finally through open fields to the plant—a total walk of about 1.5 miles. I reached the works about 3 P. M. Mr. Scheitzow took me through the plant.

28 I learned from him that the approximate quantities of material removed from the sewage at the disposal works were as follows:

- (a) From the two grit chambers, one cbm. (1.3 cu. yds.) daily.
- (b) From the scum boards and bar screens, one cbm. (1.3 cu. yds.) daily.
- (c) From the revolving screens, 10 (13.0 cu. yds.) to 12 cbm. (15.7 cu. yds.) daily.

We went first to see the coarse screens and scum boards. The scum boards were not giving good results, because the velocity of sewage passing them was too great, and they were making trials with different arrangements of the boards. The sewage flowing into the plant here was quite fresh and had no strong, disagreeable smell.

At the time of my visit, only one of the disc screens was in operation, and the difference in level of the sewage on the two sides was only 30 cm. (11.8 inches.)

I was told that the disc screens sometimes required washing with a hose once every hour to remove fat and grease. At other times, one washing on each eight-hour shift is sufficient. One man can look after the ordinary operation of all four screens.

The material removed from the sewage is piled in the yard and either given away or sold as a fertilizer. The material from the grit chambers is a black, sandy substance that dries to an earth like street dirt. I examined a long pile of it in the yard, and the odor was almost imperceptible. The material from the bar screens is black and earthy, with more leaves, rags, etc., in it than in the

29 material from the grit chambers. I saw a long pile of this in the yard, and the odor was slight. These two materials are only fair fertilizers and are given away to the farmers. The screenings from the disc screens are taken to long wooden troughs in the yard. These troughs have false bottoms built like grills, so that the liquid from the screenings can drain out and flow back to the plant. The troughs are roofed over, but not housed in. In them the screenings drain and dry, so that from 100 cu. (130.7 cu. yds.) of raw screenings, there is left only 30 (39.2 cu. yds.) to 40 cu. (42.3 cu. yds.) of dry material. This is said to be a very good fertilizer, and farmers take it away, paying 50 pf. a cu. (about 10 cents per cu. yd.) There was no accumulation of it at the plant. This material was very offensive, giving off the characteristic pig-pen odor.

Attached is a very complete description of the works, dated August, 1911. The quantities given to me by the superintendent are somewhat more liberal than those quoted in the articles. This is marked Appendix VII.

Conditions of River Water Below the Plant.—I walked from the plant down along the river about one-third of a mile to the sewer outlet, and then about half a mile farther down to a ferry, where I crossed over to the north side of the river. The river water was dirty and dark-appearing all the way down. At the outlet there was no perceptible bubbling up of sewage, nor any further discoloration evident from the shore. No sea-gulls were in evidence. From the sewer outlet to the ferry, I noticed a slight but distinct odor and there were a few blotches of sleek evident on the surface.

30 Near the ferry two men on the bank were fishing and about half-a-mile below the ferry some boys were in swimming.

As I walked along, the velocity of floating particles on the surface was about $2\frac{1}{2}$ to 3 miles per hour.

Around the wharf where the ferry landed, and at logs along the shore, scum collected to a slight extent.

Summary of Observations.—1. That the discharge of the effluent from the sewage screening plant of Dresden into the Elbe increased the unpleasantness of the river water.

2. That there were evidences of sewage pollution, such as the sleek which collected along the shore, the floating particles and the sewage odor.

3. That the greatest odor from the sewage treatment came from the storage and distribution of screenings.

31

Frankfort.

September 4th.

Description.—Frankfort is a city of about 420,000 people in Germany, on the River Main, in the southern part of Germany. The greater part of the town lies north of the river. There are no other important streams or waterways in the city. Frankfort is more of a

commercial and manufacturing city than Dresden, but not so much as Hamburg. The sewage, however, contains more solid matter than is found in the sewages of most German cities, the amount of solids being about 1300 parts per million. (For map of city see Appendix VIII.)

The city is sewered on the combined system, and the sewage from the whole city is clarified at one disposal plant located on the south side of the river, about one mile below the city. The disposal plant is located on a large tract of land owned by the city, and is not near many houses. The city refuse incinerator is adjacent to the sewage disposal works. These disposal works are different from those at Hamburg and Dresden, because in addition to removing the heavy suspended matter in the grit chamber and some of the coarser suspended matter on the screens, they also further clarify the sewage in settling basins. In this way a greater proportion of the "settleable" solids is removed, but there are more opportunities for the sewage to become septic. The percentage removal in the different stages of the clarification are given as follows, the percentages being based on the total suspended solids in the raw sewage:

Removed in grit chamber and screens.....	21%
Removed in settling basins.....	56%
Total removed	77%

This data is published in the accompanying descriptive pamphlet marked Appendix IX.

As is common in German cities, the sewers are well built, with good slopes, and the sewage comes to the plant in a fairly fresh condition. I should say, however, that it was not as fresh as at Dresden and Hamburg. The daily sewage flow to the plant generally varies from 85,000 cbm. (22,454,450 gal.) to 120,000 cbm. (31,700,000 gal.). The sewage from the north side is siphoned under the river to the disposal plant.

The Main was very low at the time of my visit. The quantity of water flowing in the river was given to me as follows:

Minimum flow....	70 cbm. per sec. (1,597,700,160 gal. per day)
Average flow.....	100 " " " (2,282,428,800 " " ")
Maximum flow....	300-400 cbm. per sec. (6,847,286,400—9,129,715,200 gal. per day)

At the time of my visit, it was a dark, unsightly water having a surface velocity of two to three miles per hour. I could easily walk faster than particles floating on the surface. The river is used for small boats and barges. The shipping is increasing but is not great, and the surface was smooth; there was comparatively little agitation of the water by boats. There are bathing places on the river front in the city and above the sewer outlet.

33 Disposal Works.—The sewage disposal plant consists of:

- (1) A grit chamber.
- (2) Three screens of the revolving paddle wheel type.
- (3) Fourteen covered settling basins.
- (4) Sludge pumping machinery.
- (5) Centrifugal machines for drying the screenings and sludge.
- (6) Conveyors, conduits, by-passes for rain water, etc.

The grit chamber and screens are located together in a house of substantial and attractive brick construction. The settling basins are covered over with an arched roof, which supports a well laid out lawn, cut with paths and gardens. There are numerous flower-beds about the plant, which is very attractive to look at. There are also attractive offices and quarters for the workmen.

The grit chamber is 6 meters (19.7 ft.) long and about 12 meters (39.4 ft.) wide, and has a bottom with rounded corners into which a cup conveyor fits. This conveyor is on a traveling carriage, so that by swinging the conveyor and moving the carriage the whole grit chamber can be cleaned. I was told at the plant that the quantity of sand removed from the grit chamber amounted to from 10 (13.0 cu. yds.) to 15 cbm. (19.9 cu. yds.) per day, and that it was cleaned daily. The grit is taken to the centrifugal machines, where it is dried and then burned in the incinerator.

There are three screens, each having five paddles and each requiring 3 h. p. to operate it. Each screen is 2 meters (6.6 ft.) wide, and the clear spacing between the bars is 10 millimeters (0.39 inches). The screens are cleaned mechanically by brushes which force the leaves, rags, feces, etc., off the end of the paddles on to a belt conveyor. The screens take from 2 to 4 minutes per revolution, and the speed can be varied to suit the flow of sewage. I was told at the plant that the screens removed from 15 (19.9 cu. yds.) to 20 cbm. (26.1 cu. yds.) daily.

Each of the fourteen settling tanks is 5.8 meters (19.0 ft.) wide by about 41 meters (134.5 ft.) long and 2.5 meters (8.2 ft.) deep. The velocity of flow in them is not over 8 millimeters (0.312 inches) per second, and the period of flow is about 80 minutes. From 6 to 8 tanks are in operation at a time. Each tank is allowed to run for two days, when the supernatant sewage is drawn off and the wet sludge is pumped to the centrifugal machines. When drawn, each tank contains about 400 cbm. (522 cu. yds.) of wet sludge. Therefore the daily quantity of sludge from each tank amounts to about 40 cbm. (52.2 cu. yds.) and with seven tanks in operation, this would amount to 280 cbm. (366 cu. yds.) daily of wet sludge. Six tanks were in operation at the time of my visit.

The bottom of each basin slopes toward two ramps, from which the sludge is pumped to the centrifugal machines. The basins are lined with white glazed brick, to avoid deposits and to facilitate cleaning. The pumping is done by two vacuum tanks, which operate like suction pumps delivering into a force main. They pump the sludge through an iron pipe 30 cm. (11.8 inches) in diameter to the centrifugal machines about 200 yards away. The difference in elevation between the settling tanks and the sludge

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tanks of the centrifugal machines is about 17 meters (55.7 ft.) and the dynamic head is 25 meters (82.0 ft.)

The sludge drying plant consists of four sludge tanks over the centrifugal machines, eight so-called centrifuges, a hot air drier in the basement, and the necessary hoists and conveyors for delivering the dried sludge into the hoppers over the furnaces of the incinerator. Each centrifugal machine has a capacity of 3 cbm. (3.9 cu. yds.) of wet sludge per hour, and it is necessary to keep 4 to 6 machines running every day. The drier in the basement is heated with waste gases from the incinerator.

It is interesting to note that up to the latter part of the year 1909, the sludge and screenings from the Frankfort plant were disposed of on land. On account of the unreliability of this method of sludge disposal, the centrifugal machines described above were installed. This is a costly method of disposal, but gets the sludge and screenings out of the way without great nuisance.

Work Done.—I spent only Monday, Sept. 4th, in Frankfort. In the morning I went to the city hall and talked with Ing. Schaefer, and in the afternoon I visited the disposal works, where I was shown through by the chief foreman in the absence of the superintendent.

General Conditions During Visit.—The day of my visit was a clear, hot, sunny day, with very little wind; the temperature being about 80° F. There was no rain on that day and there had been almost none for several weeks previous. The Main was very low.

Visit to Disposal Works, Sept. 4.—I went to the disposal works partly by trolley and partly on foot. From the trolley I walked down along the river bank for about three-quarters of a mile. Along this part of the river there were quite a number of gardens and there were houses up to about three-eighths of a mile from the works. Just before coming to the works, I passed the unloading station, where the scows bringing the refuse boxes from the city are unloaded. The neighborhood was not critical but was not so isolated as at Dresden.

I went first into the house containing the grit chamber and screens. The velocity through this part of the works was quite rapid (say about 4 feet per second), and the odor was not bad. One of the screens was not operating on the day of my visit.

Going into the tank house, the odor was more distinct. In the masonry roof over each tank there is an opening or vent, through which the gases from the tanks escape. I afterward went close to one of these vents where it opened into the air and got no very bad smell.

Six tanks were in operation when I was at the plant, and all of them had a heavy scum, especially the main distributing channel at the center.

The centrifugal house smelled like a reduction plant, only not so strongly. This odor came from handling the dried sludge in the cars and conveyors. The odor was not so strong as the odor from the screenings at Dresden and Hamburg. The material coming out of the drier was a black, moist, fine, earthy material that smelled like the tankage from a garbage reduction plant.

Condition of Main Water.—After going through the plant, I went down to the main sewage outlet below the plant. There was one seagull there, and the foreman told me there were many there during stormy weather. Two or three miles below, I could see the chimneys of a small town. The effluent was discharged about one-fourth of the width of the river from shore. The effluent was very plain to see as it "boiled" up out of the dark river water. It looked like a thick, light-brown colored liquid, and it made a long, clearly marked area in the river water, extending for at least a quarter of a mile below the point of discharge.

I was told that at this point the river was about six meters (19.7 ft.) deep and that the bottom was gravelly; and that no deposits formed on the bottom.

The odor from the effluent was faint—not as evident as at Dresden.

Summary of Observations.—1. That the discharge of the effluent from the sewage disposal works of Frankfort into the Main materially increased the unsightliness of the river water.

2. That there were evidences of sewage pollution, such as the boiling or bubbling up of the sewage plant effluent in the river water and the clearly marked sewage area extending down stream from the point of discharge.

38 3. That the city, after disposing of the sludge and screenings on land for a number of years, had gone to great expense to dry and then burn the sludge and screenings from the sewage works.

Respectfully submitted,

SAMUEL A. GREELEY.

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APPENDIX I.

List of Drawings and Documents.

Those secured:

- (1) Tide tables for Hamburg, 1911 (Appendix II.)
- (2) Die Sielanlagen Hamburgs (Appendix III-A).
- (3) Hamburger Förderrechen (Appendix III-B).
- (4) Map of Hamburg (Appendix IV).
- (5) Hamburgische Elb-Untersuchung (Appendix V).
- (6) Map of Dresden (Appendix VI).
- (7) Beschreibung der Anlagen zur Reinigung und Hebung der Dresdner Kanalwasser (Appendix VII).
- (8) Map of Frankfort (Appendix VIII).
- (9) Müllverbrennungs und Abwasserklär-Anlage Frankfort-am-Main (Appendix IX).

Those to be secured:

- (1) A description of the Hamburg sewers and sewage disposal works—by Curt Merkel.

(2) Der Wasserbau—Die Entwässerung der Städte—by August Fröhling (gives some data on stream flow).

(3) Wasser und Abwasser—Die Hygiene der Wasserversorgung und Abwasserbeseitigung—by Kollwitz, Reichle, Schmidtman, Spitta, and Thumm. Verlag S. Hirzel, Leipzig, 1911.

40 (4) Maps of Germany may be secured from Die Kgl. Preussische Geologische Landesanstalt Berlin.
Photographs—Ten of sewage works at Hamburg.

APPENDIX II.

Tide Tables for Hamburg, 1911.

(Here follows reproduction of four pages of tide tables for Hamburg.

42 Hundbuch der Hygiene, by Thumm-Schmidtman, etc.

1911.

Summary of all work done at Royal Testing Station & throughout Germany.

Die Finsternisse des Jahres 1911.

Im Jahre 1911 werden zwei, für unsere Gegenden nicht sichtbare, Sonnenfinsternisse stattfinden. Der Mond wird in diesem Jahre nicht verfinstert.

Die erste Sonnenfinsternis ist eine totale und ereignet sich in der Nacht vom 28. zum 29. April. Sie beginnt bei der Lord-Howe-Insel im Oken von Australien am 28. April um 8 Uhr 49 Min. abends, überkreuzt die östliche Hälfte des australischen Kontinents und Neu-Seeland, zieht über die Mitte des Stillen Ozeans und erstreckt sich über Mittelamerika und die südliche Hälfte Nordamerikas. Sie endet am 29. April um 2 Uhr 6 Min. morgens in der Gegend zwischen Acapulco an der mexikanischen Küste und der Clipperton-Insel.

Die zweite Sonnenfinsternis findet am Vormittag des 22. Oktober statt. Sie ist eine ringförmige und beginnt um 2 Uhr 19 Min. morgens in der Nähe von Lahore. Das Gebiet der Sichtbarkeit erstreckt sich über den größten Teil des asiatischen Kontinents mit Ausnahme von Kleinasien, Palästina, dem westlichen Arabien und dem im Oken der Vena gelegenen Teil Sibiriens; ferner über Australien mit Ausnahme der Südwestküste des letzten und über die westliche Hälfte Südamerikas. Die Finsternis endet im Südosten der Salomon-Inseln um 8 Uhr 7 Min. vormittags.

Geschichtliche Erinnerungen.

Das Jahr 1911 der christlichen Ära ist das

- 6624. der Julianischen Periode;
- 3672. der Juden (Beginn derselben am 28. September, I. E. 3 u. 16);
- 1946. seit der Einführung des Julianischen Kalenders durch Julius Cäsar;
- 1841. nach der Befreiung Jerusalems durch Titus;
- 1111. seit der Krönung Karls des Großen zum römischen Kaiser;
- 1108. seit der Gründung Hamburgs (nach alter, nicht völlig sicherer Annahme);
- 1125. seit Gründung des Bistums Bremen durch Karl den Großen;
- 1080. seit der Gründung eines Erzbistums in Hamburg durch Ludwig den Frommen;
- 949. seit der Krönung Otto des Ersten zum römischen Kaiser;
- 768. seit der Gründung des jetzigen Lübeds;
- 471. seit der Erfindung der Buchdruckkunst;
- 458. seit dem Ende des oströmischen Kaiserthums und der Eroberung Konstantinopels durch die Turken;
- 419. seit der Entdeckung Amerikas;
- 394. seit dem Beginn der Reformation durch Martin Luther;
- 329. seit der Kalenderverbesserung durch Papst Gregor XIII.;
- 290. seitdem die Reichsstadt (das spätere Michaelisfeld) zur Stadt gezogen wurde;
- 135. seit der Einführung des „allgemeinen Reichs-Kalenders“;
- 69. seit dem letzten großen Brand in Hamburg (5. bis 8. Mai 1842);
- 56. seit der letzten großen Sturmflut (20. 1.);
- 52. seit der Einführung der neuen Verfassung in Hamburg;
- 43. seitdem die Reichsstadt St. Georg zu Hamburg gezogen wurde;
- 41. laufende Jahr von der Neubegründung des Deutschen Reiches im Januar 1871 an;
- 23. seit dem Tode Kaiser Wilhelms I.

Mitteleuropäische Zeit. (M. E. Z.)

Alle Angaben in diesem Kalender sind auf M. E. Z. berechnet. Für Sonnen- und Mond-Auf- und Untergang gilt die Breite und der Meridian von Hamburg. Die nachfolgende Tafel gibt die Differenzen zwischen M. E. Z. und M. O. Z. Um mittlere Ortszeit zu bekommen, hat man zu den Zeitangaben des Kalenders für die folgenden Orte + zu addieren — zu subtrahieren.

Hachen —36 Min.	Düsseldorf —33 Min.	Parlbrücke —26 Min.	Wien —11 Min.
Altona —20 „	Hamburg —31 „	Raffel —22 „	Velen + 8 „
Hamburg —16 „	Hilbing +18 „	Riel —19 „	Potsdam — 8 „
Harmen —31 „	Grün —16 „	Röln —32 „	Prag — 2 „
Helen —30 „	Hfen —32 „	Rönigsberg +22 „	Regensburg —12 „
Helen — 8 „	Hensburg —23 „	Reich —34 „	Roth —11 „
Hern —30 „	Hernf. a. H. —25 „	Selbig —10 „	St. Gallen —23 „
Hochum —31 „	Hernf. a. E. — 2 „	Siegen — 5 „	Schwerin —14 „
Honn —32 „	Hreiburg. H. —29 „	Sied —17 „	Stettin — 8 „
Hraunschw. —18 „	Hürth —16 „	Wagdeburg —15 „	Stralsburg —29 „
Bremen —25 „	Hent —35 „	Wain —27 „	Stuttgart —23 „
Breslau + 8 „	Hera —12 „	Wannheim —26 „	Trier —33 „
Bromberg +12 „	Hirken —25 „	Wemel —24 „	Trier — 5 „
Charlottenb. — 7 „	Hörlich — 0 „	Weg —35 „	Wlm —29 „
Chemnitz — 8 „	Hotha —17 „	Wühlhausen —30 „	Weimar —15 „
Curhaven —25 „	Hraz + 2 „	Würchen —14 „	Wien + 5 „
Danzig —15 „	Halle a. E. —12 „	W. Glabbach —34 „	Wickhausen —27 „
Darmstadt —25 „	Hamburg —20 „	Würster —29 „	Wittenbur —25 „
Dortmund —30 „	Hannover —21 „	Würzburg —16 „	Würzburg —20 „
Dresden — 3 „	Heidelberg —25 „	Wittenburg —27 „	Wittenburg —26 „
Duisburg —33 „	Hefelohnd —28 „	Wittenburg —28 „	Wittenburg —10 „

(Exhibit No 204)

Datum	Juli			August			September			Oktober			November			Dezember		
	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe	Normittag Hut Ebbe
1.	4.4	8.4	4.4	5.4	9.4	5.4	10.4	5.4	10.4	5.4	10.4	6.4	11.4	7.4	12.4	7.4	12.4	8.4
2.	5.5	9.5	5.5	6.5	10.5	6.5	11.5	6.5	11.5	6.5	12.5	7.5	13.5	8.5	14.5	8.5	15.5	9.5
3.	6.6	10.6	6.6	7.6	11.6	7.6	12.6	7.6	13.6	7.6	14.6	8.6	15.6	9.6	16.6	9.6	17.6	10.6
4.	7.7	11.7	7.7	8.7	12.7	8.7	13.7	8.7	14.7	8.7	15.7	9.7	16.7	10.7	17.7	10.7	18.7	11.7
5.	8.8	12.8	8.8	9.8	13.8	9.8	14.8	9.8	15.8	9.8	16.8	10.8	17.8	11.8	18.8	11.8	19.8	12.8
6.	9.9	13.9	9.9	10.9	14.9	10.9	15.9	10.9	16.9	10.9	17.9	11.9	18.9	12.9	19.9	12.9	20.9	13.9
7.	10.10	14.10	10.10	11.10	15.10	11.10	16.10	11.10	17.10	11.10	18.10	12.10	19.10	13.10	20.10	13.10	21.10	14.10
8.	11.11	15.11	11.11	12.11	16.11	12.11	17.11	12.11	18.11	12.11	19.11	13.11	20.11	14.11	21.11	14.11	22.11	15.11
9.	12.12	16.12	12.12	13.12	17.12	13.12	18.12	13.12	19.12	13.12	20.12	14.12	21.12	15.12	22.12	15.12	23.12	16.12
10.	13.13	17.13	13.13	14.13	18.13	14.13	19.13	14.13	20.13	14.13	21.13	15.13	22.13	16.13	23.13	16.13	24.13	17.13
11.	14.14	18.14	14.14	15.14	19.14	15.14	20.14	15.14	21.14	15.14	22.14	16.14	23.14	17.14	24.14	17.14	25.14	18.14
12.	15.15	19.15	15.15	16.15	20.15	16.15	21.15	16.15	22.15	16.15	23.15	17.15	24.15	18.15	25.15	18.15	26.15	19.15
13.	16.16	20.16	16.16	17.16	21.16	17.16	22.16	17.16	23.16	17.16	24.16	18.16	25.16	19.16	26.16	19.16	27.16	20.16
14.	17.17	21.17	17.17	18.17	22.17	18.17	23.17	18.17	24.17	18.17	25.17	19.17	26.17	20.17	27.17	20.17	28.17	21.17
15.	18.18	22.18	18.18	19.18	23.18	19.18	24.18	19.18	25.18	19.18	26.18	20.18	27.18	21.18	28.18	21.18	29.18	22.18
16.	19.19	23.19	19.19	20.19	24.19	20.19	25.19	20.19	26.19	20.19	27.19	21.19	28.19	22.19	29.19	22.19	30.19	23.19
17.	20.20	24.20	20.20	21.20	25.20	21.20	26.20	21.20	27.20	21.20	28.20	22.20	29.20	23.20	30.20	23.20	31.20	24.20
18.	21.21	25.21	21.21	22.21	26.21	22.21	27.21	22.21	28.21	22.21	29.21	23.21	30.21	24.21	31.21	24.21	1.22	25.21
19.	22.22	26.22	22.22	23.22	27.22	23.22	28.22	23.22	29.22	23.22	30.22	24.22	31.22	25.22	1.23	25.22	2.23	26.22
20.	23.23	27.23	23.23	24.23	28.23	24.23	29.23	24.23	30.23	24.23	31.23	25.23	1.24	26.23	2.24	26.23	3.24	27.23
21.	24.24	28.24	24.24	25.24	29.24	25.24	30.24	25.24	31.24	25.24	1.25	26.24	2.25	27.24	2.25	27.24	4.25	28.24
22.	25.25	29.25	25.25	26.25	30.25	26.25	31.25	26.25	1.26	27.25	2.26	28.25	3.26	28.25	3.26	28.25	5.26	29.25
23.	26.26	30.26	26.26	27.26	31.26	27.26	1.27	28.26	2.27	28.26	3.27	29.26	4.27	29.26	4.27	29.26	6.27	30.26
24.	27.27	31.27	27.27	28.27	1.28	28.27	3.28	29.27	4.28	29.27	5.28	30.27	6.29	30.27	5.28	30.27	7.29	31.27
25.	28.28	1.29	28.28	29.28	2.29	29.28	4.29	30.28	5.30	30.28	6.31	31.28	7.32	31.28	6.31	31.28	8.32	1.29
26.	29.29	2.30	29.29	30.29	3.30	30.29	5.31	31.29	6.32	31.29	7.33	1.30	8.34	1.30	7.33	31.29	9.33	2.30
27.	30.30	3.31	30.30	31.30	4.31	31.30	6.33	1.31	7.34	1.31	8.35	2.31	9.35	2.31	8.35	1.31	10.34	3.31
28.	31.31	4.32	31.31	1.32	5.32	1.32	7.35	2.32	8.36	2.32	9.36	3.32	10.36	3.32	9.36	2.32	11.35	4.32
29.	1.32	5.33	1.32	2.33	6.33	2.33	8.37	3.33	9.37	3.33	10.37	4.33	11.37	4.33	10.37	3.33	12.36	5.33
30.	2.33	6.34	2.33	3.34	7.34	3.34	9.38	4.34	10.38	4.34	11.38	5.34	12.38	5.34	11.38	4.34	1.37	6.34
31.	3.34	7.35	3.34	4.35	8.35	4.35	10.39	5.35	11.39	5.35	12.39	6.35	1.40	6.35	12.39	5.35	2.38	7.35

(Exhibit. no 204)

Eintritt der Blut und Ebbe in Guxhaven 1911. Niedrigwasser = Eintritt der Blut. Hochwasser = Eintritt der Ebbe.

Datum	Januar				Februar				März				April				Mai				Juni			
	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut	Seemittag Blut
1.	8 1/2	1 1/2	8 3/4	1 3/4	9 1/2	2 1/2	9 3/4	2 3/4	8 1/2	1 1/2	8 3/4	2 1/2	9 1/2	2 1/2	9 3/4	2 3/4	8 1/2	1 1/2	8 3/4	2 1/2	9 1/2	2 3/4	9 3/4	2 1/2
2.	9 1/2	2 1/2	9 3/4	2 3/4	10 1/4	3 1/4	10 3/4	3 3/4	9 1/2	2 1/2	9 3/4	2 3/4	10 1/4	3 1/4	10 3/4	3 3/4	9 1/2	2 1/2	9 3/4	2 3/4	10 1/4	3 1/4	10 3/4	3 3/4
3.	10 1/2	3 1/2	10 3/4	3 3/4	11 1/4	4 1/4	11 3/4	4 3/4	10 1/2	3 1/2	10 3/4	3 3/4	11 1/4	4 1/4	11 3/4	4 3/4	10 1/2	3 1/2	10 3/4	3 3/4	11 1/4	4 1/4	11 3/4	4 3/4
4.	10 3/4	4 1/4	11 1/4	4 3/4	11 3/4	5 1/4	12 1/4	5 3/4	11 1/2	4 1/2	11 3/4	5 1/4	12 1/4	5 3/4	12 3/4	6 1/4	11 1/2	4 1/2	11 3/4	5 1/4	12 1/4	5 3/4	12 3/4	6 1/4
5.	11 1/2	5 1/2	12 1/4	5 3/4	12 3/4	6 1/4	13 1/4	6 3/4	12 1/2	5 1/2	12 3/4	6 1/4	13 1/4	6 3/4	13 3/4	7 1/4	12 1/2	5 1/2	12 3/4	6 1/4	13 1/4	6 3/4	13 3/4	7 1/4
6.	12 1/2	6 1/2	13 1/4	6 3/4	13 3/4	7 1/4	14 1/4	7 3/4	13 1/2	6 1/2	13 3/4	7 1/4	14 1/4	7 3/4	14 3/4	8 1/4	13 1/2	6 1/2	13 3/4	7 1/4	14 1/4	7 3/4	14 3/4	8 1/4
7.	1 1/4	7 1/4	1 3/4	7 3/4	2 1/4	8 1/4	2 3/4	8 3/4	1 1/2	7 1/2	1 3/4	7 3/4	2 1/4	8 1/4	2 3/4	8 3/4	1 1/2	7 1/2	1 3/4	7 3/4	2 1/4	8 1/4	2 3/4	8 3/4
8.	2 1/4	8 1/4	2 3/4	8 3/4	3 1/4	9 1/4	3 3/4	9 3/4	2 1/2	8 1/2	2 3/4	8 3/4	3 1/4	9 1/4	3 3/4	9 3/4	2 1/2	8 1/2	2 3/4	8 3/4	3 1/4	9 1/4	3 3/4	9 3/4
9.	3 1/4	9 1/4	3 3/4	9 3/4	4 1/4	10 1/4	4 3/4	10 3/4	3 1/2	9 1/2	3 3/4	9 3/4	4 1/4	10 1/4	4 3/4	10 3/4	3 1/2	9 1/2	3 3/4	9 3/4	4 1/4	10 1/4	4 3/4	10 3/4
10.	4 1/4	10 1/4	4 3/4	10 3/4	5 1/4	11 1/4	5 3/4	11 3/4	4 1/2	10 1/2	4 3/4	10 3/4	5 1/4	11 1/4	5 3/4	11 3/4	4 1/2	10 1/2	4 3/4	10 3/4	5 1/4	11 1/4	5 3/4	11 3/4
11.	5 1/4	11 1/4	5 3/4	11 3/4	6 1/4	12 1/4	6 3/4	12 3/4	5 1/2	11 1/2	5 3/4	11 3/4	6 1/4	12 1/4	6 3/4	12 3/4	5 1/2	11 1/2	5 3/4	11 3/4	6 1/4	12 1/4	6 3/4	12 3/4
12.	6 1/4	12 1/4	6 3/4	12 3/4	7 1/4	13 1/4	7 3/4	13 3/4	6 1/2	12 1/2	6 3/4	12 3/4	7 1/4	13 1/4	7 3/4	13 3/4	6 1/2	12 1/2	6 3/4	12 3/4	7 1/4	13 1/4	7 3/4	13 3/4
13.	7 1/4	13 1/4	7 3/4	13 3/4	8 1/4	14 1/4	8 3/4	14 3/4	7 1/2	13 1/2	7 3/4	13 3/4	8 1/4	14 1/4	8 3/4	14 3/4	7 1/2	13 1/2	7 3/4	13 3/4	8 1/4	14 1/4	8 3/4	14 3/4
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15.	9 1/4	15 1/4	9 3/4	15 3/4	10 1/4	16 1/4	10 3/4	16 3/4	9 1/2	15 1/2	9 3/4	15 3/4	10 1/4	16 1/4	10 3/4	16 3/4	9 1/2	15 1/2	9 3/4	15 3/4	10 1/4	16 1/4	10 3/4	16 3/4
16.	10 1/4	16 1/4	10 3/4	16 3/4	11 1/4	17 1/4	11 3/4	17 3/4	10 1/2	16 1/2	10 3/4	16 3/4	11 1/4	17 1/4	11 3/4	17 3/4	10 1/2	16 1/2	10 3/4	16 3/4	11 1/4	17 1/4	11 3/4	17 3/4
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18.	12 1/4	18 1/4	12 3/4	18 3/4	13 1/4	19 1/4	13 3/4	19 3/4	12 1/2	18 1/2	12 3/4	18 3/4	13 1/4	19 1/4	13 3/4	19 3/4	12 1/2	18 1/2	12 3/4	18 3/4	13 1/4	19 1/4	13 3/4	19 3/4
19.	1 1/2	1 1/2	1 3/4	1 3/4	2 1/4	2 1/4	2 3/4	2 3/4	1 1/2	1 1/2	1 3/4	1 3/4	2 1/4	2 1/4	2 3/4	2 3/4	1 1/2	1 1/2	1 3/4	1 3/4	2 1/4	2 1/4	2 3/4	2 3/4
20.	2 1/4	2 1/4	2 3/4	2 3/4	3 1/4	3 1/4	3 3/4	3 3/4	2 1/2	2 1/2	2 3/4	2 3/4	3 1/4	3 1/4	3 3/4	3 3/4	2 1/2	2 1/2	2 3/4	2 3/4	3 1/4	3 1/4	3 3/4	3 3/4
21.	3 1/4	3 1/4	3 3/4	3 3/4	4 1/4	4 1/4	4 3/4	4 3/4	3 1/2	3 1/2	3 3/4	3 3/4	4 1/4	4 1/4	4 3/4	4 3/4	3 1/2	3 1/2	3 3/4	3 3/4	4 1/4	4 1/4	4 3/4	4 3/4
22.	4 1/4	4 1/4	4 3/4	4 3/4	5 1/4	5 1/4	5 3/4	5 3/4	4 1/2	4 1/2	4 3/4	4 3/4	5 1/4	5 1/4	5 3/4	5 3/4	4 1/2	4 1/2	4 3/4	4 3/4	5 1/4	5 1/4	5 3/4	5 3/4
23.	5 1/4	5 1/4	5 3/4	5 3/4	6 1/4	6 1/4	6 3/4	6 3/4	5 1/2	5 1/2	5 3/4	5 3/4	6 1/4	6 1/4	6 3/4	6 3/4	5 1/2	5 1/2	5 3/4	5 3/4	6 1/4	6 1/4	6 3/4	6 3/4
24.	6 1/4	6 1/4	6 3/4	6 3/4	7 1/4	7 1/4	7 3/4	7 3/4	6 1/2	6 1/2	6 3/4	6 3/4	7 1/4	7 1/4	7 3/4	7 3/4	6 1/2	6 1/2	6 3/4	6 3/4	7 1/4	7 1/4	7 3/4	7 3/4
25.	7 1/4	7 1/4	7 3/4	7 3/4	8 1/4	8 1/4	8 3/4	8 3/4	7 1/2	7 1/2	7 3/4	7 3/4	8 1/4	8 1/4	8 3/4	8 3/4	7 1/2	7 1/2	7 3/4	7 3/4	8 1/4	8 1/4	8 3/4	8 3/4
26.	8 1/4	8 1/4	8 3/4	8 3/4	9 1/4	9 1/4	9 3/4	9 3/4	8 1/2	8 1/2	8 3/4	8 3/4	9 1/4	9 1/4	9 3/4	9 3/4	8 1/2	8 1/2	8 3/4	8 3/4	9 1/4	9 1/4	9 3/4	9 3/4
27.	9 1/4	9 1/4	9 3/4	9 3/4	10 1/4	10 1/4	10 3/4	10 3/4	9 1/2	9 1/2	9 3/4	9 3/4	10 1/4	10 1/4	10 3/4	10 3/4	9 1/2	9 1/2	9 3/4	9 3/4	10 1/4	10 1/4	10 3/4	10 3/4
28.	10 1/4	10 1/4	10 3/4	10 3/4	11 1/4	11 1/4	11 3/4	11 3/4	10 1/2	10 1/2	10 3/4	10 3/4	11 1/4	11 1/4	11 3/4	11 3/4	10 1/2	10 1/2	10 3/4	10 3/4	11 1/4	11 1/4	11 3/4	11 3/4
29.	11 1/4	11 1/4	11 3/4	11 3/4	12 1/4	12 1/4	12 3/4	12 3/4	11 1/2	11 1/2	11 3/4	11 3/4	12 1/4	12 1/4	12 3/4	12 3/4	11 1/2	11 1/2	11 3/4	11 3/4	12 1/4	12 1/4	12 3/4	12 3/4
30.	12 1/4	12 1/4	12 3/4	12 3/4	13 1/4	13 1/4	13 3/4	13 3/4	12 1/2	12 1/2	12 3/4	12 3/4	13 1/4	13 1/4	13 3/4	13 3/4	12 1/2	12 1/2	12 3/4	12 3/4	13 1/4	13 1/4	13 3/4	13 3/4
31.	1 1/2	1 1/2	1 3/4	1 3/4	2 1/4	2 1/4	2 3/4	2 3/4	1 1/2	1 1/2	1 3/4	1 3/4	2 1/4	2 1/4	2 3/4	2 3/4	1 1/2	1 1/2	1 3/4	1 3/4	2 1/4	2 1/4	2 3/4	2 3/4

THE PEOPLE OF THE STATE OF NEW YORK,
COMPLAINANTS,

VS.

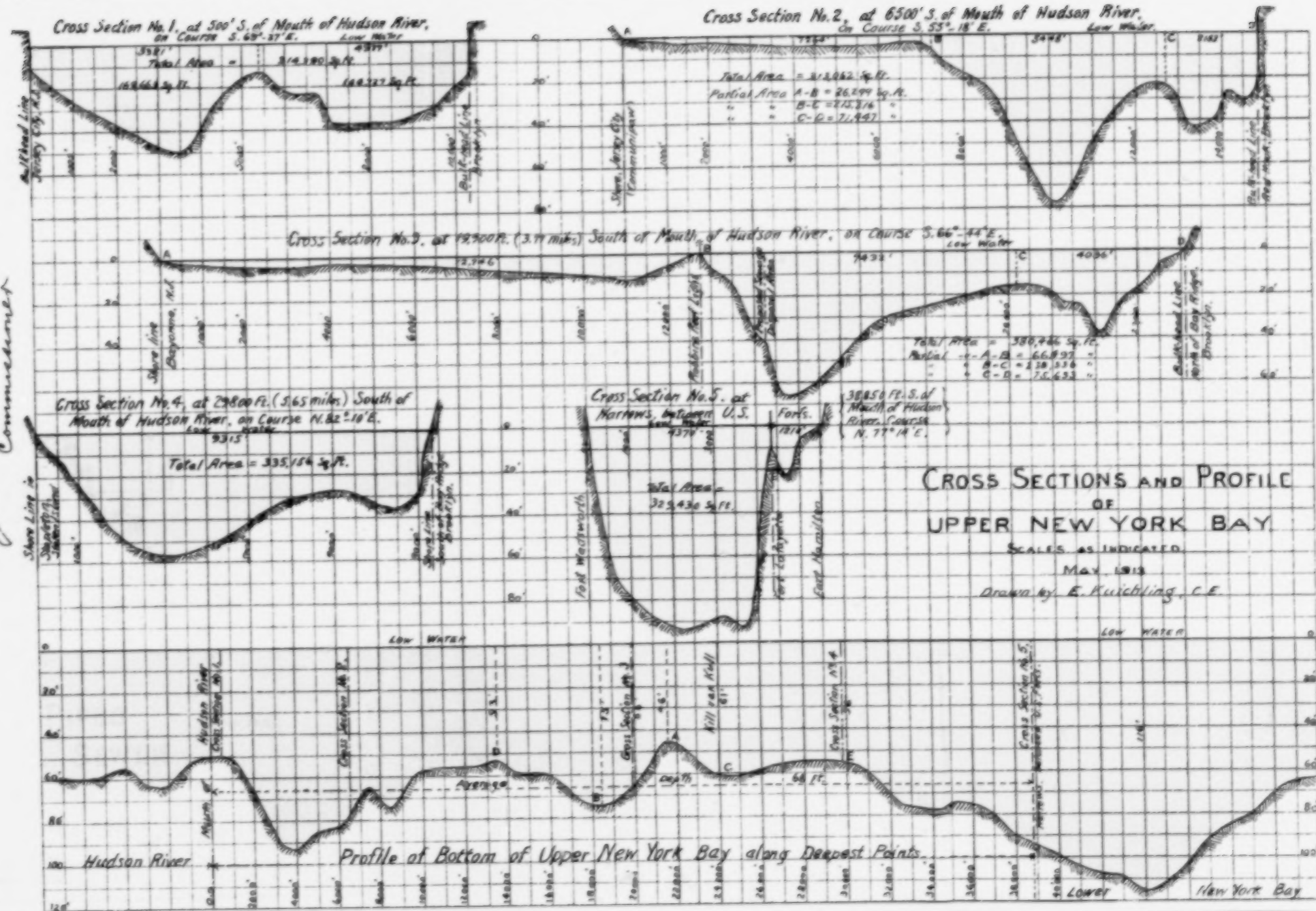
STATE OF NEW JERSEY ET AL.

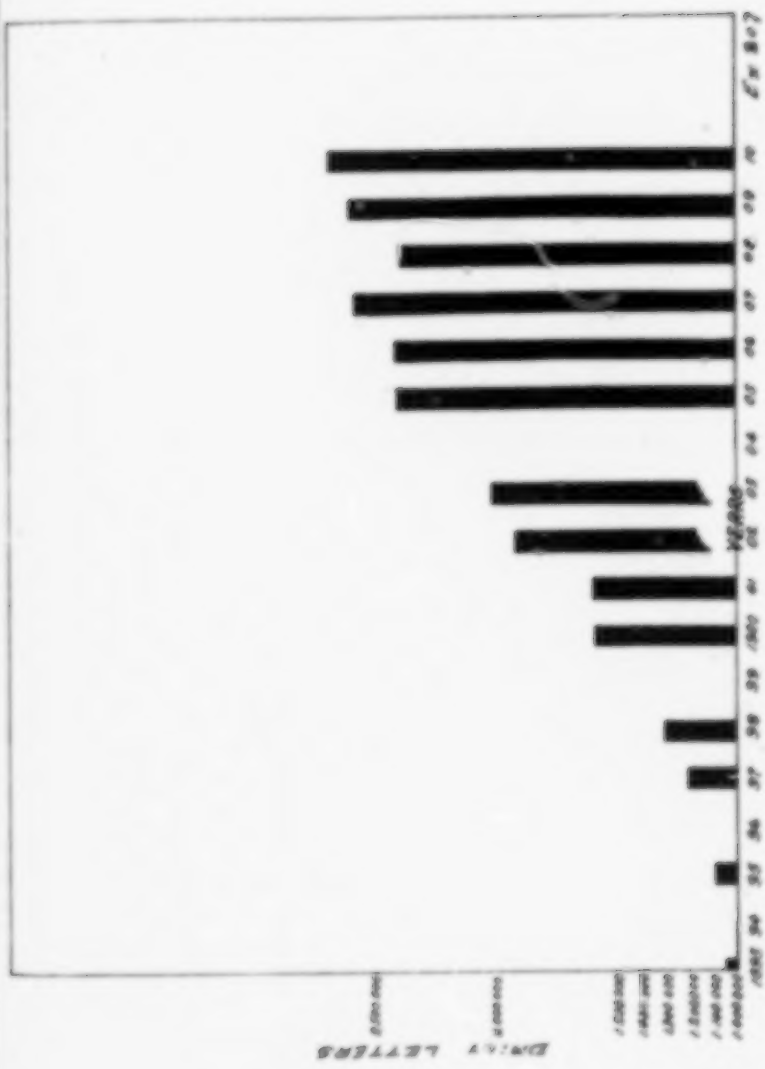
HERE FOLLOW COMPLAINANTS' EXHIBITS

Nos. 205, 206, 207, 208, 209, 210, 211, 211a, 212a,
212b, 212c, 212d, 213, and 214.

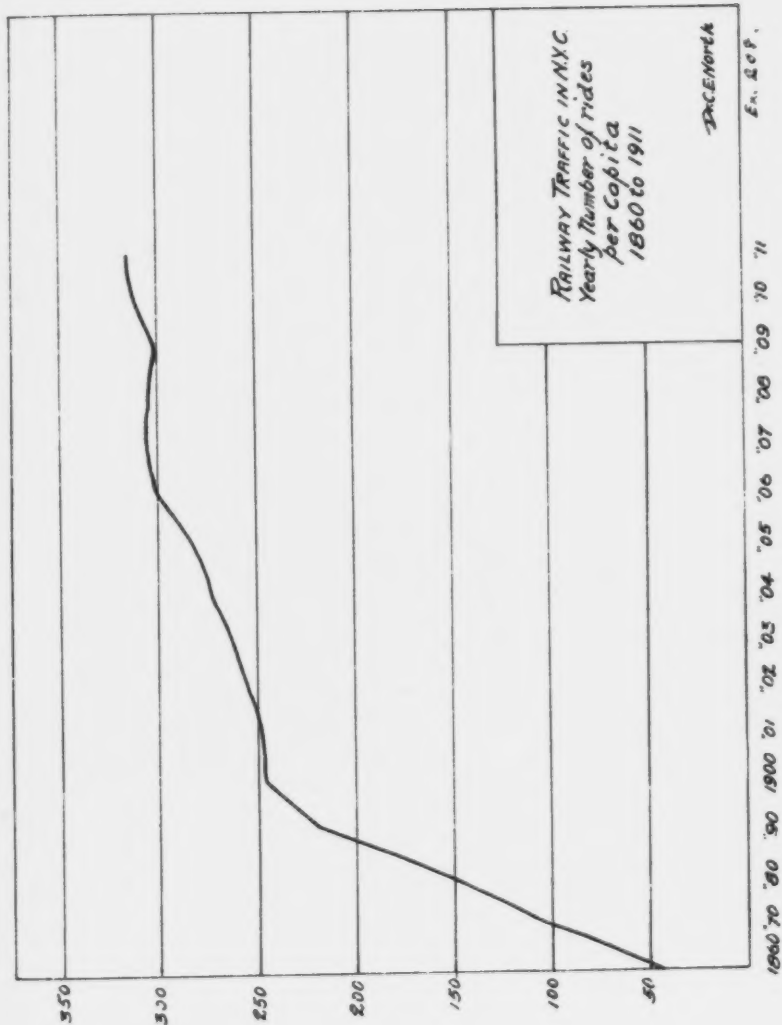
JAMES D. MAHER,
Commissioner.

Complainants Exhibit No. 205
James H. Maher
Commissioner

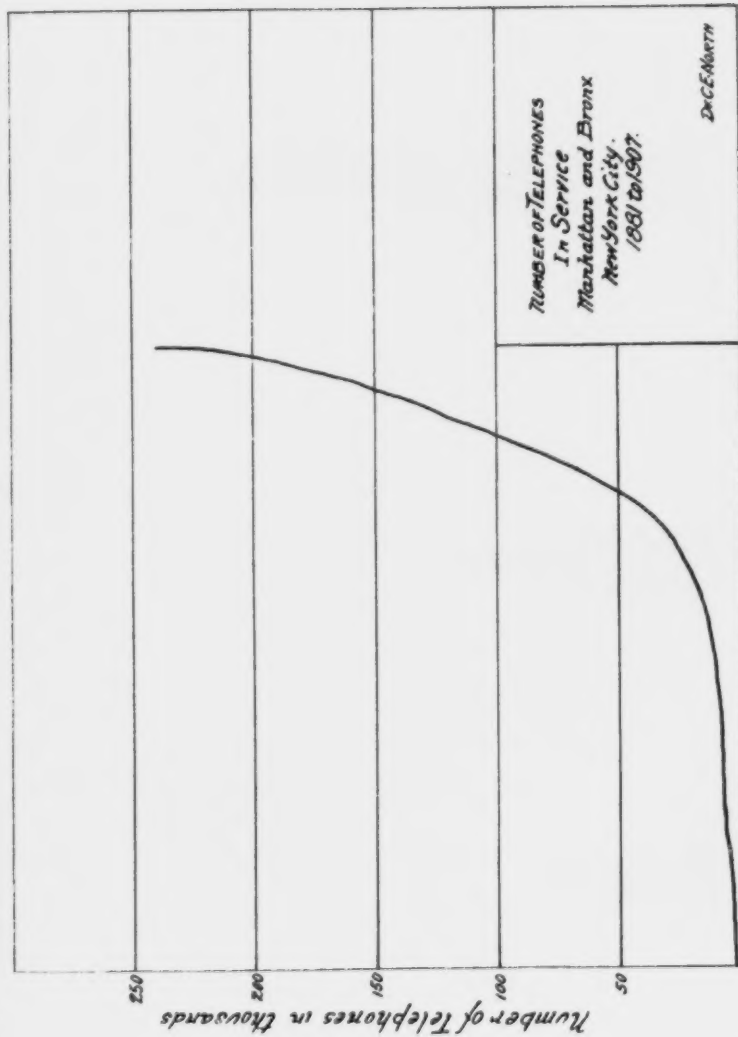












1881 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10

E. C. - 204

Growth of Population and Business

New York City.

P = Population

L = LETTERS

R = Railroad Passengers

T = Telephone Calls

Tp = Telegraphs

P.L.R.T.Tp.

P.L.R.T.Tp.

P.L.R.T.Tp.

Ex 210

1910

1900

1890

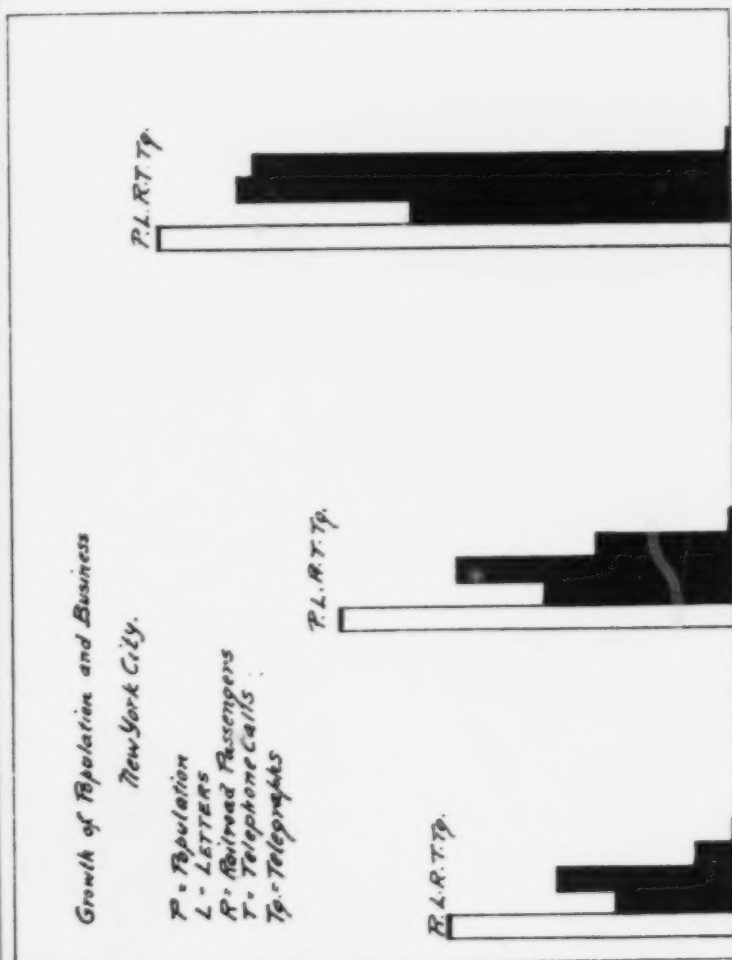
5mill

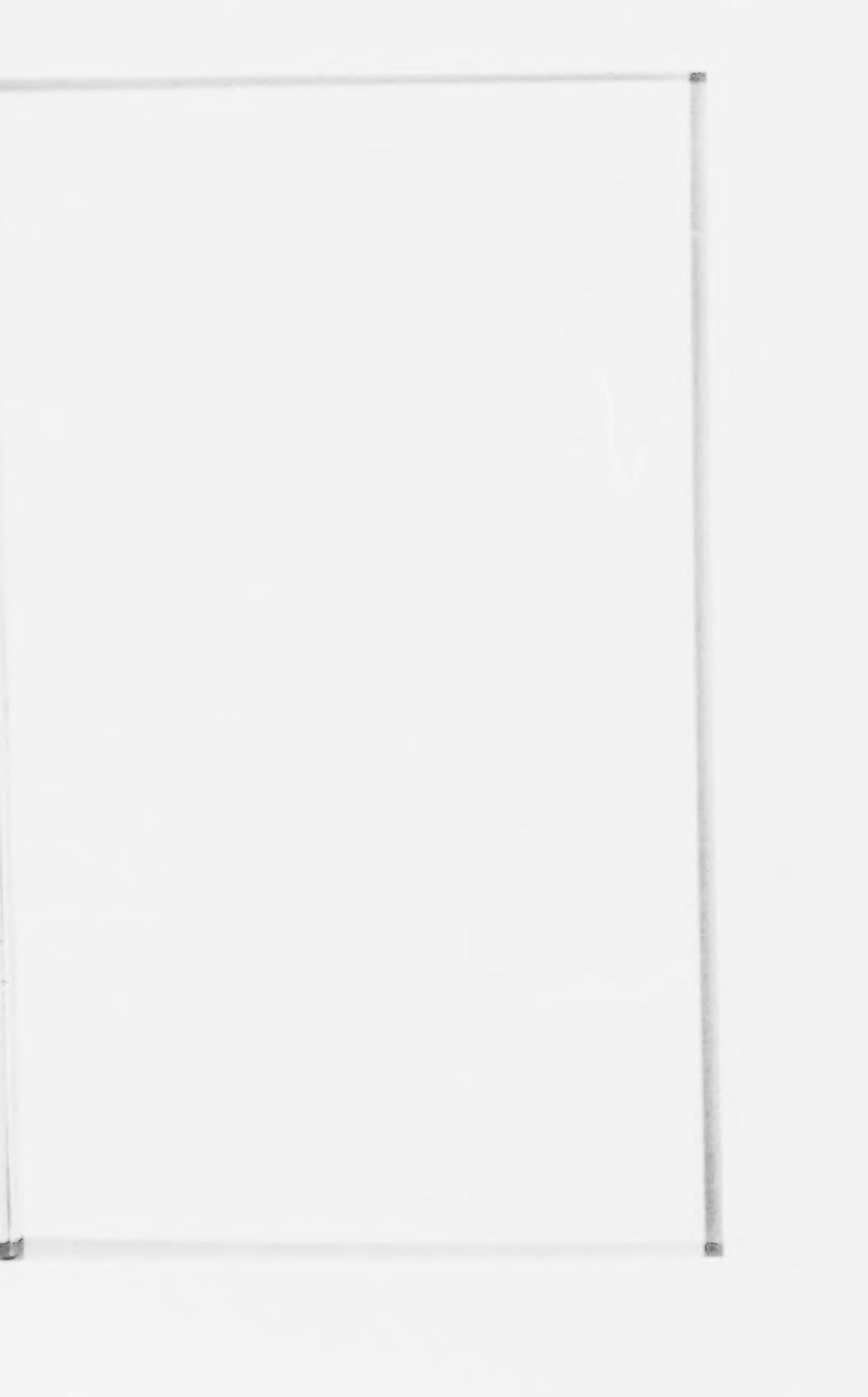
4mill

3mill

2mill

1mill



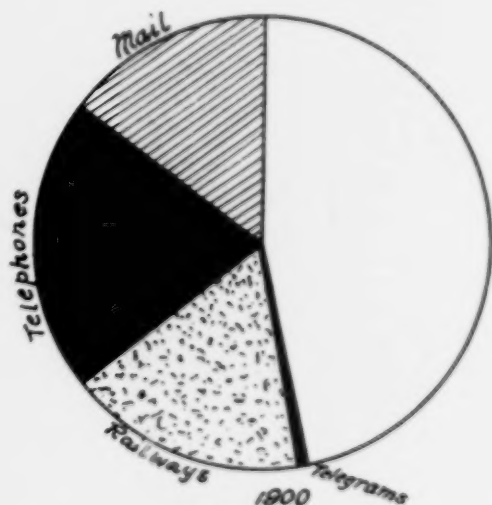


Increase Business Pressure
per Capita NYC in 20 Years.

Chart No. 6
Charles E. Hall, M.D.



1890.
391.64 Transactions



1900
965.15 Transactions

Ex. 211



Stock Corporations
Formed Each Year
New York City
1900 - 1912

From Annual Report Secy. State
New York Dec. 1912

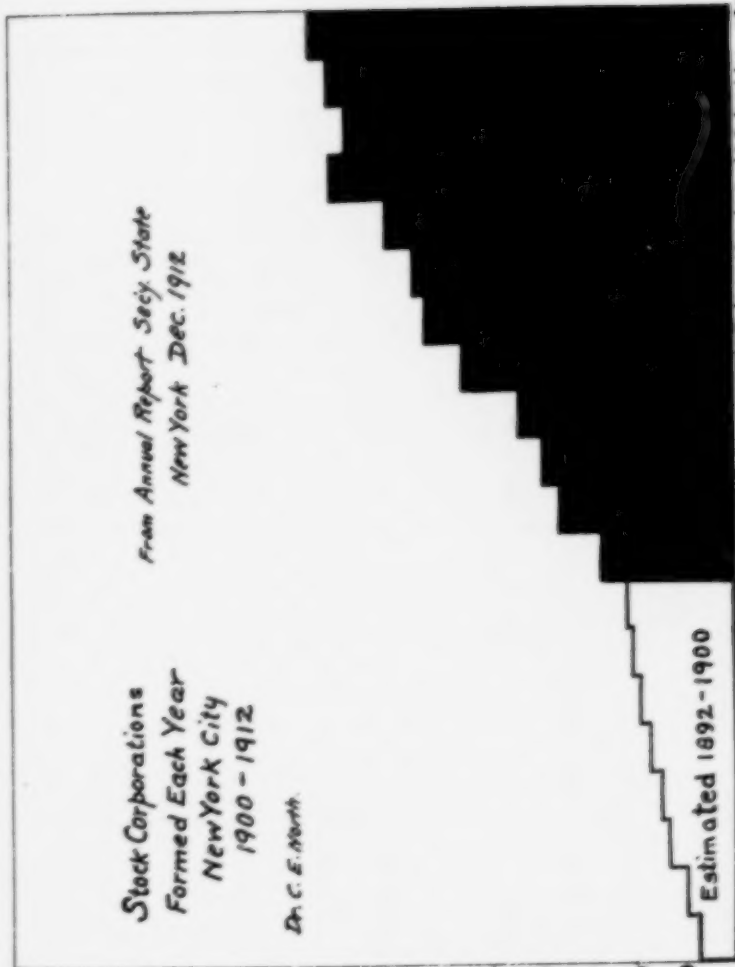
Dr. C. E. North.

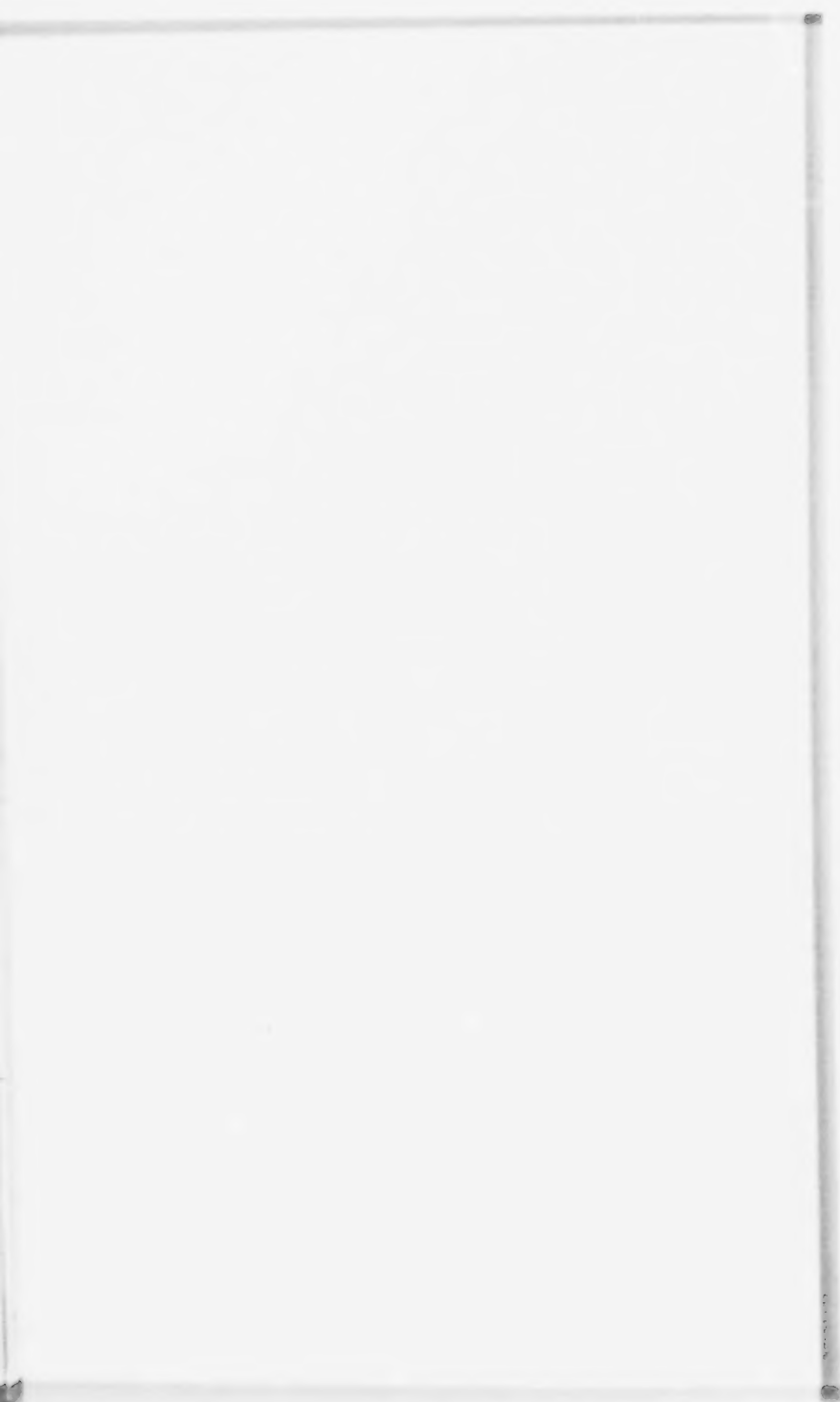
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000

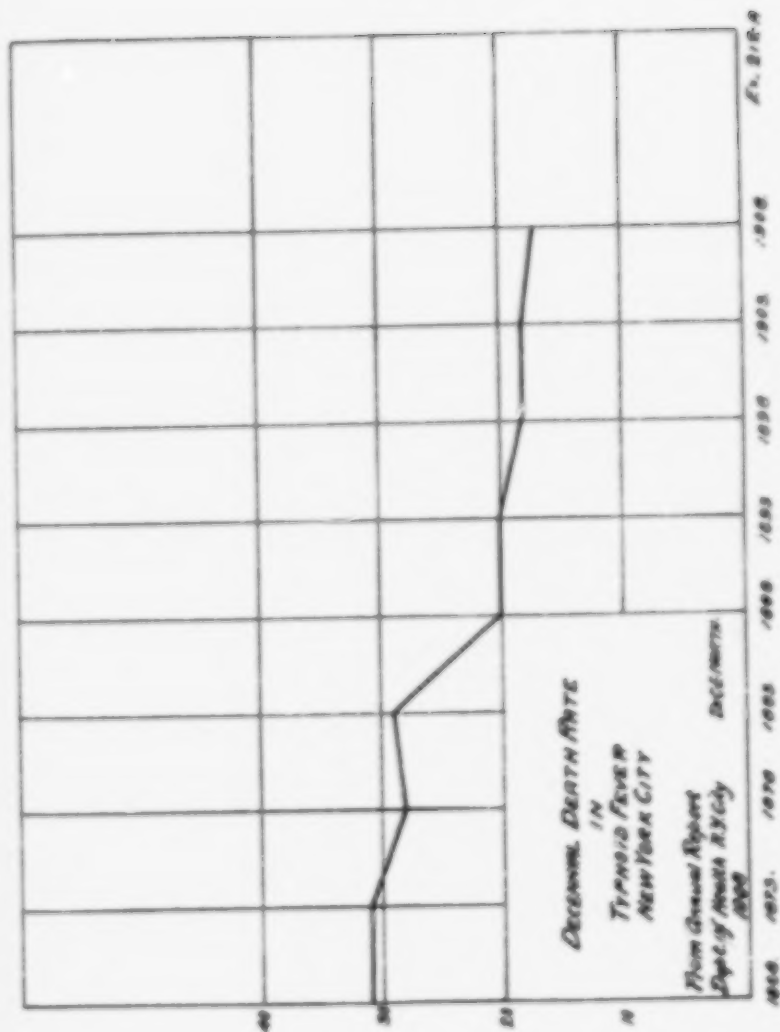
Estimated 1892-1900

1892 '93 '94 '95 '96 '97 '98 '99 '00 '01 '02 '03 '04 '05 '06 '07 '08 '09 '10 '11 '12

Ex. 211-2

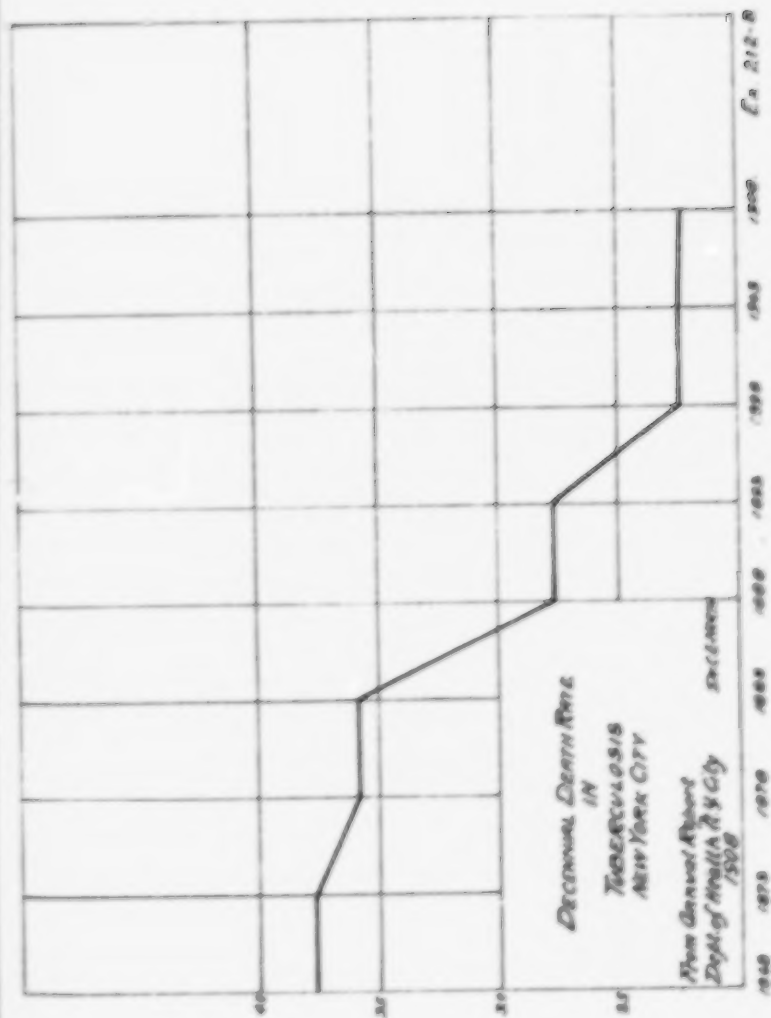


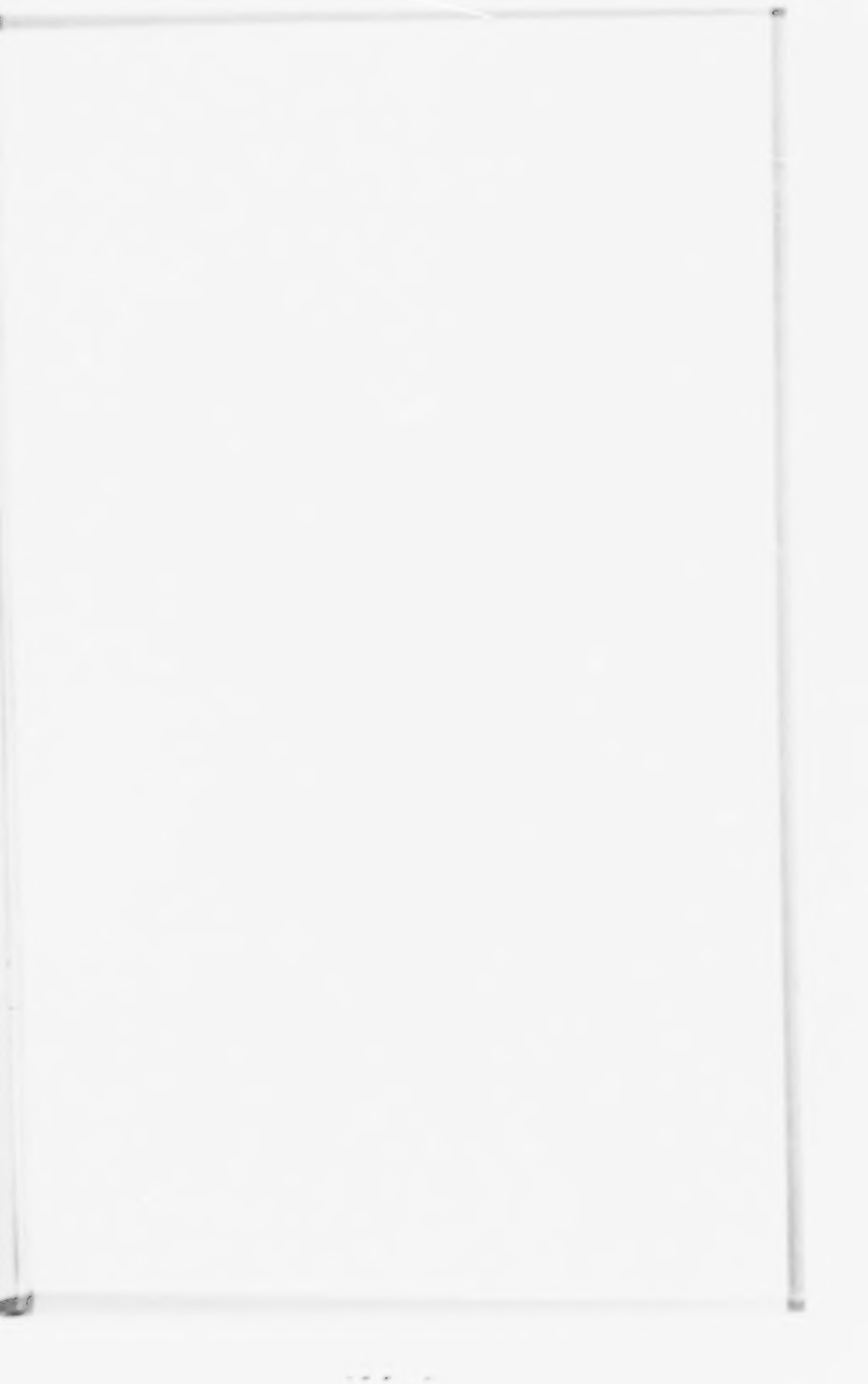


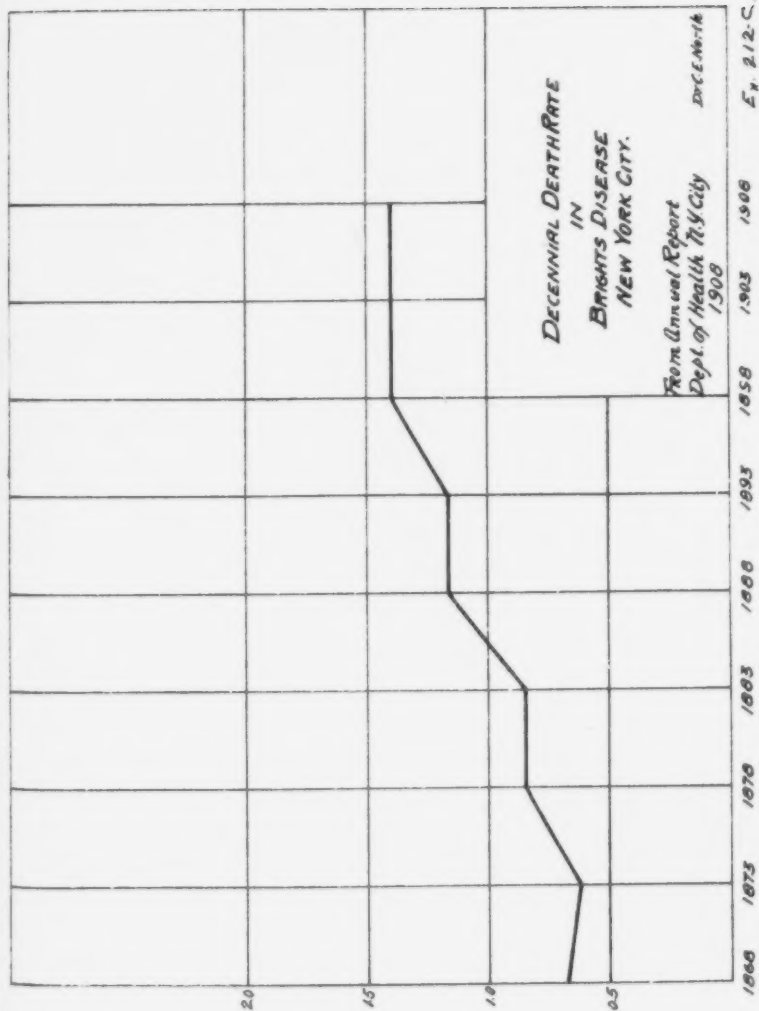


Ex. 215-2

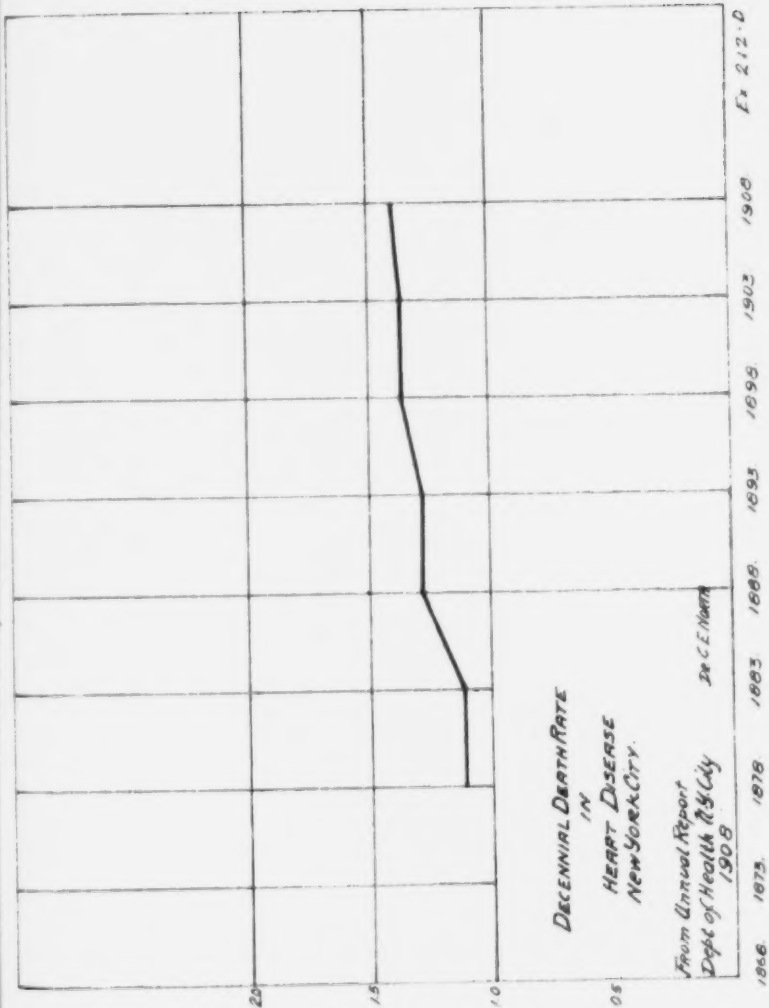




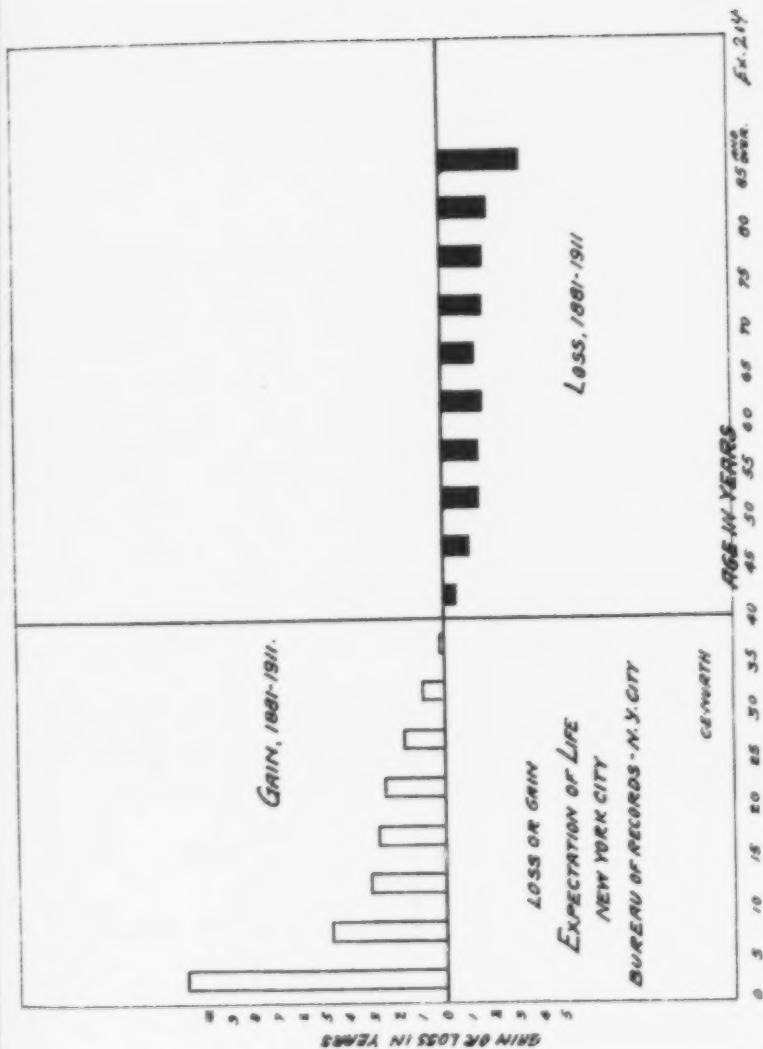




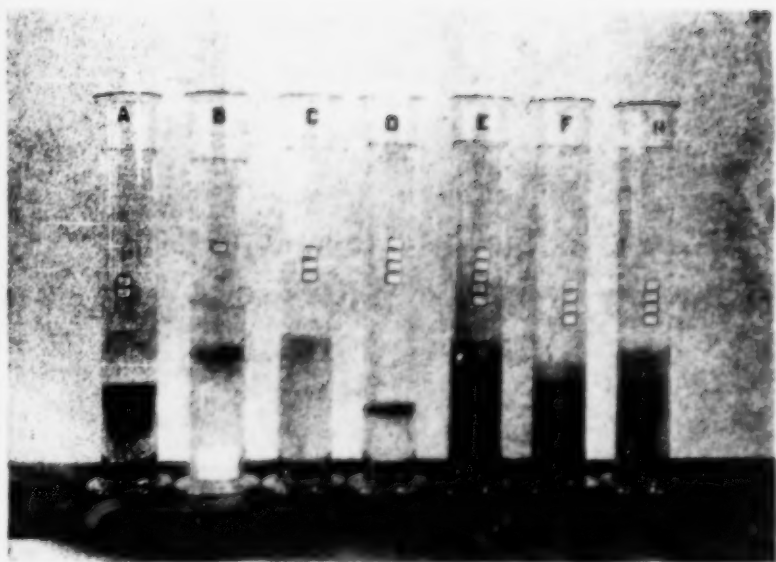












(Exhibit 215 - Page 3)



- 1 COMPLAINTANTS' EXHIBIT NO. 215. James D. Maher, Commissioner.

Effect of Salinity and Direction of Discharge on the Ascent of Fresh Water in Salt Water.

Edward Ellery.

- 2 COMPLAINTANTS' EXHIBIT NO. 215. James D. Maher, Commissioner.

Effect of Salinity and Direction of Discharge on the Ascent of Fresh Water in Salt Water.

Edward Ellery.

(Here follows diagram showing ascent of fresh water in salt water, marked Exhibit 215, page 3.)



4

Explanation of the Photograph.

Cylinder "A." Water of 14,019 parts Chlorine per million under fresh water. Dye solution delivered in lower layer in upward direction. After ten days standing.

Cylinder "B." Water of 14,019 parts Chlorine per million under water of 7,009 parts Chlorine per million. Dye solution delivered in lower layer in upward direction. After ten days standing.

Cylinder "C." Water of 6,754 parts Chlorine per million under water 3,377 parts per million. Dye delivered in lower layer in upward direction. After ten days standing.

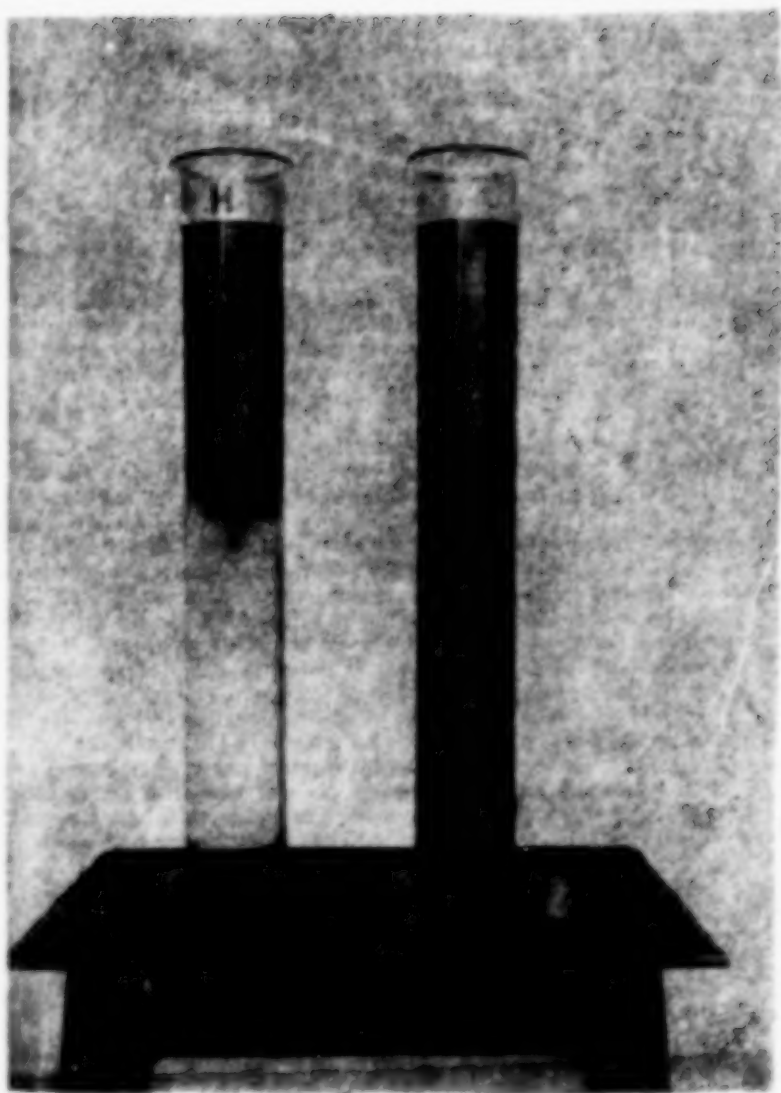
Cylinder "D." Water of 8,500 parts Chlorine per million under water of 6,500 parts per million. Dye solution delivered in lower layer in upward direction. After three days standing.

Cylinder "E." Water of 8,500 parts Chlorine per million under water of 8,000 parts per million. Dye solution delivered in lower layer in downward direction. After two days standing.

Cylinder "F." Water of 8,500 parts Chlorine per million under water of 7,500 parts per million. Dye solution delivered downward, in lower layer. After two days standing.

Cylinder "G." Water of 8,500 parts Chlorine per million under water of 7,000 parts per million. Dye solution delivered in downward direction in lower layer. After two days standing.

(Here follows diagram marked Exhibit 215, page 5.)



(Exhibit 215, page 5)

6 Cylinder "H," Water of 8,500 parts Chlorine per million.
Dye solution delivered about eight inches from the bottom,
in an upward direction. After two hours standing.

Cylinder with no letter shows how the waters looked when the dye solution had diffused itself throughout the entire column.

7 Foreword

In his testimony in the case of New York vs. New Jersey and The Passaic Valley Sewerage Commission, Mr. Geo. A. Johnson, witness for the defendant, testified as follows, regarding a certain dye experiment performed by him:

1. 30,000 gallons of water heavily charged with an aniline dye were pumped into the bay, 10, 20, 30, and 40 feet below the surface at rates varying from 1.8 to 2 cu. ft. per second (pages 3976-77).

2. Strength of dye solution was $\frac{2}{3}$ of a pound to 1,000 gallons of water, or about 1 part dye in 11,500 parts water by weight (page 3977).

3. The discharge pipe pointed vertically downward (page 3997).

4. At the hour of discharge into the deepest water both surface and bottom currents were of the same velocity and in the same direction (numbers 3078-3082).

5. The salinity of the water was 8,500 parts Chlorine per million, about 46% sea water (page-3979-3982).

6. The inference is drawn that when fresh water sewage, discharged as proposed through outlets, some 150 in number, and located at a depth of 40 ft., or more below the surface, will undergo a sufficiently complete diffusion in the waters of New York Bay so as not to rise to the surface in objectionable quantities if at all, and merely if at all in visible quantities" (page 3982-3983).

The following study shows what conditions must be taken into consideration before any interpretation can be made of the results of discharging fresh water into salt water, and in the absence of such details in Mr. Johnson's testimony regarding his experiment

8 he had no sufficient basis for his inference, and further his inference is erroneous.

Outline of the Experiments.

1. Effect of direction of discharge of fresh water into salt waters when the latter is of the same degree of salinity throughout.

II. Effect of delivering fresh water in an upward direction into salt water consisting of layers of different degrees of salinity.

III. Effect of delivering fresh water in a downward direction into salt water consisting of layers of different degrees of salinity.

General Conclusions

1. When fresh water is discharged in a downward direction into salt water of the same degree of salinity throughout, it first continues to move downward and then moves upward to the surface.



2. When fresh water is discharged sidewise into salt water of the same degree of salinity throughout, it rises to the surface at once.

3. When fresh water is discharged in an upward direction into salt water of the same degree of salinity throughout it rises to the surface at a more rapid rate than in either case 1 or 2.

4. When fresh water is discharged in an upward direction into salt water consisting of different layers of varying degrees of salinity, it comes to the surface at once, except in cases of large difference in salinity of the layers.

5. When fresh water is discharged in a downward direction into salt water consisting of layers of different degrees of salinity, it rises only to the top of the lower layer and remains there for periods of time varying from two to ten days.

6. Therefore the question of whether fresh water discharged into salt water will come to the surface or not, depends on two conditions; first, the direction of discharge, and second, difference in salinity in different layers of the water into which the discharge takes place.

Apparatus Used in the Study.

For the purposes of this study tall cylinders were used 28 inches high and 4 inches in diameter. These were filled with 4 liters of water. To the water varying amounts of salt accurately weighed were added, and thoroughly mixed to insure the homogeneity of the solution. In the cases in which different layers of water were required in the same cylinder, the heavier water was delivered at the bottom of a lighter water by means of an elongated funnel tube reaching to the bottom of the cylinder.

For delivering the dye solution three long glass tubes were used of the same calibre, one straight throughout its length for delivery in a downward direction, one with a bend at right angle for delivery sidewise, and one with the end bent to deliver the solution in an upward direction. These tubes were graduated in order that the same amount of dye solution might be delivered at each trial and at the same velocity.

Two dyes were used, one known as "Special Scarlet", referred to by the Metropolitan Sewerage Commission in its report for 1910, page 458, and one known as "Red 2R", presumably the one referred to by Mr. Johnson in his testimony (page 3977). These are azo-dyes of similar chemical structure, are both soluble in water to a deep red solution, and both give easily distinguishable color in extremely dilute solutions.

The strength of the solution in each case was eighty parts of dye to a million parts of water, or in other words one part to 12,500, the strength Mr. Johnson used in his experiment (page 3977-3978).

*Results of the Series.***I.**

Conditions: Homogeneous solution.

Delivery down, sidewise and up.

Time noted when color reached the surface.

Salinity parts chlorine per million.	Delivered down.	Delivered sidewise.	Delivered up.
	Less than 5 min.	Less than 5 min.	Less than 5 min.
6,754	" "	" "	" "
7,098	" "	" "	" "
7,266	" "	" "	" "
8,055	" "	" "	" "
9,006	" "	" "	" "
9,590	" "	" "	" "
10,009	" "	" "	" "
13,062	" "	" "	" "
13,703	" "	" "	" "
14,500	" "	" "	" "
16,098	" "	" "	" "
17,098	" "	" "	" "

11

Conclusion.

When delivered into salt water varying in salinity from 6,754 parts chlorine per million (36.5% sea water) to 17,098 parts chlorine per million (96.5% sea water) fresh water rises at once to the surface, and the direction of the discharge does not make any further difference than to affect the rate of rise.

II.

Conditions: Two layers, salt water, of different degrees of salinity.
Delivery in upward direction.

For this series cylinders were prepared as follows:

1. Water of 14,019 parts Chlorine per million under fresh water Cylinder "A" of the photograph.
2. Water of 14,019 parts Chlorine per million under water of 7,009 parts Chlorine per million. Cylinder "B" of the photograph.
3. Water of 6,754 parts Chlorine per million under water of 3,377 parts Chlorine per million. Cylinder "C" of the photograph.
4. Water of 8,500 parts Chlorine per million under water of 8,000 parts Chlorine per million.
5. Water of 8,500 parts Chlorine per million under water of 7,500 parts Chlorine per million.

6. Water of 8,500 parts Chlorine per million under water of 7,000 parts Chlorine per million.

7. Water of 8,500 parts Chlorine per million under water of 6,500 parts Chlorine per million.

Cylinder "D" of the photograph.

12

Results.

1. No color in the upper layer after ten days. All in lower layer.

2. No color in upper layer after ten days. Color diffused through lower layer but most of it at the junction on the two layers.

3. No color in the upper layer, after ten days. Color evenly diffused through lower layer.

4. Color reached the surface in less than five minutes.

5. Some color reached the top in less than five minutes, but heavy line of color was noticeable between the layers after an hour.

6. Some color reached the top in less than five minutes, but heavy line of color was noticeable between the layers after two hours.

7. No color had reached the top after three days.

The photograph shows these results very distinctly and the sharp line of division between the different layers.

Conclusion.

Fresh water delivered upward at the velocity of these experiments in the lower of two layers of salt water of different degrees of salinity, does not rise to the surface if the difference in salinity is 11% or more.

III.

Conditions: Two layers, salt water, of different degrees of salinity. Delivery in downward direction.

In this series a blank determination was first made with five cylinders of water of different degrees of salinity, starting with a water containing 8,500 parts chlorine per million, the salinity observed by Mr. Johnson at the time of his experiment (pages 3979-3982).

13 The following results were noted:

Salinity
parts chlorine
per million.

Dye solution delivered downward.

8,500.....	Reached the surface in less than five minutes.
8,000.....	" " " " " " " "
7,500.....	" " " " " " " "
7,000.....	" " " " " " " "
6,500.....	" " " " " " " "

Cylinders were then prepared as follows:

1. Water of 8,500 parts Chlorine per million under water of 8,000 parts per million.

Cylinder "E" of photograph.

2. Water of 8,500 parts Chlorine per million under water of 7,500 parts per million.

Cylinder "F" of photograph.

3. Water of 8,500 parts Chlorine per million under water of 7,000 parts per million.

Cylinder "G" of photograph.

4. Water of 8,500 parts Chlorine per million under water of 6,500 parts per million.

The dye solution was delivered downward as in the blank in the bottom layer of each cylinder, with the following results, shown very clearly in the photograph:

1. Distinct stratification as shown by the color in the lower layer after 48 hours.

2. Ditto.

3. Ditto.

4. Ditto.

After six days the stratification was still distinct in "4" but the color had diffused in that time throughout the *the* others.

14

Conclusion.

When fresh water is delivered downward in salt water consisting of layers of different degrees of salinity, a very slight difference in salinity (less than three per cent) is sufficient to keep the fresh water in the lower layer although the same fresh water will rise through *through* either layer alone.

General Conclusions from I, II, and III.

It is apparent from the foregoing that direction of discharge and salinity in different layers of water into which the discharge takes place determine whether the discharged water will come to the surface or not. It seems therefore that Mr. Johnson's inference, if based upon the data given in his testimony (pages 3976-4011) and on no other, is not warranted and is untenable. It is doubtless true that under some circumstances fresh water when delivered downward into salt water will not come to the surface, but it is equally true that under other circumstances it will come to the surface. A general statement that it will or that it will not come to the surface can not be made.

It is further to be noted that in Mr. Johnson's experiment the fresh water was delivered in a downward direction while in the proposed plan of the defendant the sewage is to be delivered upward. These experiments, herein recorded, show that when fresh water is delivered upward in salt water there are fewer conditions which prevent its coming to the surface than under any other method

- 15 of delivery. A conclusion based upon the result of delivering fresh water downward into salt water is not applicable to the condition when the fresh water is delivered upward.

The differences in salinity of the layers of water off Robbins Reef are very clearly shown in the report of the Metropolitan Sewerage Commission for 1910 on page 527. "The difference between the salinity of the water at the surface and at a depth below the surface of 40 ft. was found more marked at Robbins Reef than at most other places, the surface sometimes containing 10% more land water than that near the bottom, but this condition was variable". The table of salinities given on that page of the report shows that the difference of salinity would be great enough at times to keep fresh water delivered in the lower depths downward in that stratum, but would not be great enough to keep the fresh water in the lower stratum if it were delivered upward. The report also shows on the same page that there are times when the conditions are such that the fresh water would come to the surface, whatever the direction of its discharge. The report states—

"A sample taken at Robbins Reef October 30 at 4 P. M. had a specific gravity of 1.025, indicating an entire absence of land water."

This study shows that under those circumstances or any others in which there was homogeneity in the waters fresh water will come to the surface whatever the direction of discharge.

These considerations show that Mr. Johnson did not have sufficient basis for his inference, or having it failed to give it in his testimony. They further show that whether he had more data than he gave or not his inference is erroneous.

- a COMPLAINANTS' EXHIBIT No. 216. James D. Maher, Commissioner.

THE AERATION OF WATER.

Special Topic: The Influence of Sewage Pollution.

Edward Ellery.

- 1 COMPLAINANTS' EXHIBIT No. 216. James D. Maher, Commissioner.

THE AERATION OF WATER.

Special Topic: The Influence of Sewage Pollution.

Edward Ellery.

- 2 *Foreword.*

This study of the influences that affect the rate of absorption by water of oxygen from the atmosphere is not undertaken to determine with scientific accuracy the coefficient of oxygen absorption, but is being carried on with a view to determining what actually takes place in the matter of oxygen absorption under varying conditions. The plan is to study two large volumes of water at the same time and, if possible, to change one of the variables while keeping all the others constant. It is thought that such a study will throw some light on the complex problem of aeration of water from the atmosphere.

The special topic herein treated, namely, "The Influence of Sewage Pollution," is taken up at this time under the direction of Dr. W. J. O'Sullivan, Special Counsel for New York in the case of New York vs. New Jersey and the Passaic Valley Sewerage Commission, and the results are the property of New York, to be used only as counsel in the above case may permit and direct.

General Conclusions.

1. Salt water of from 60% to 70% of the salinity of the sea water seems to absorb oxygen from the air at practically the same rate as fresh water, between the points of 40% and 60% of saturation for each. (See General Conclusions, Series I, pages 11, 12).

3 2. The absorption of oxygen by both fresh and salt water from the air is not so rapid as has been supposed. Dr. Adeney's maximum of 0.067 c. c. to 0.077 c. c. of oxygen per liter per hour seems high in the light of this study. These experiments show that the rate of absorption may vary from 0.18 c. c. per day to 0.306 c. c. per day in quiescent water and to 0.515 c. c. per day in moving water. (See General Conclusions, Series I, Page 12).

3. Whatever may be the cause of fluctuations in the amount of oxygen absorbed, it affects both fresh and salt water in the same way. (See diagram I.)

4. The greater the humidity, the less is the rate of absorption of oxygen by both fresh and salt waters. (See diagram II, III and V. Also Results, Series IIA, page 13). (Also Results, Series IIIA, Page 18.)

5. Polluted salt water absorbs oxygen at a greater rate than unpolluted. (See Results, Series IIA, pages 13; Results Series IIB, page 16; Results IIIA, page 18; Exception in the case of the second day, Series IIIA, page 18.)

6. A dilution of the proportion of one part of sewage to sixty (60) parts of salt water, when the water is quiescent, does not seem permissible, while a dilution of 1:100 does not show reduction of oxygen content below the initial content. (See Diagrams IV and VII; Results Series IIA, page 14; Results Series IIB, page 16.)

7. The average rate of absorption of oxygen by quiescent salt water may run as high as 0.306 c. c. per day, and of salt water moving at the rate of one foot per second, as high as 0.515 c. c. per day. (See Conclusions, Series IIB, page 16; Results, Series IIIA page 18).

8. Salt water moving at the rate of one foot per second seems to be able to take care of sewage in the dilution of 1:60 and possible even the dilution of 1:30. (See Results, Series IIIB, page 20; Conclusions, Series IIIA, page 19.)

9. Salt water whose oxygen content has been reduced to 3 c. c. oxygen per liter (Eddy's Standard) if quiescent will not take care of sewage discharge into it at the rate of one gallon of sewage to 60 gallons of water, but seems to be able to take care of the sewage discharged into it at the rate of one gallon of sewage to 100 gallons of water.

10. Moving salt water, containing 4.526 c. c. of oxygen per liter, seems to be able to take sewage in the proportion of 1:30 without diminution of oxygen content below 4.294 c. c.

11. The sewage disposal capacity of moving salt water seems large, if the sewage can be evenly distributed throughout its volume.

For this part of the study, waters were examined as follows:

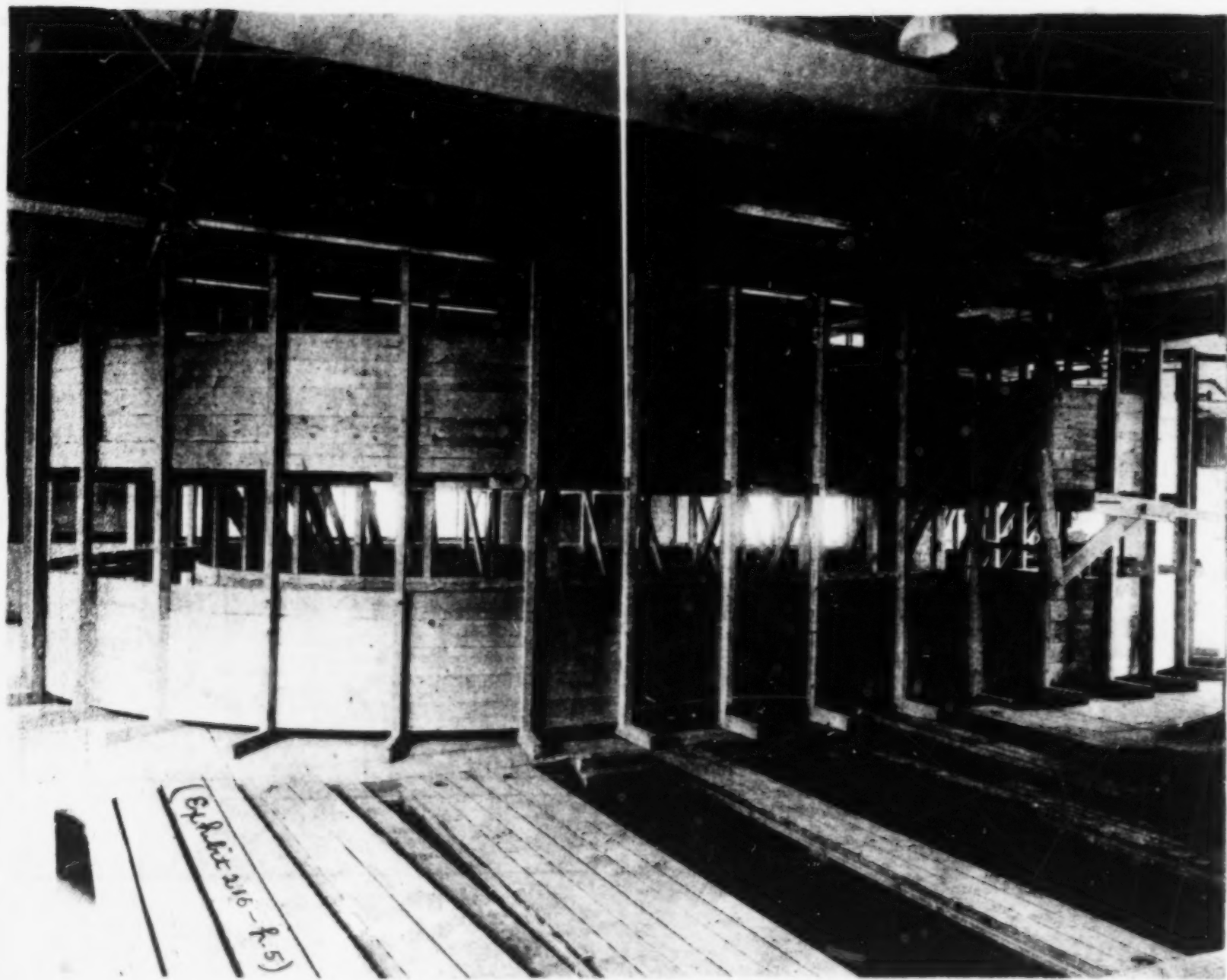
I. Fresh and Salt Water.

II. Polluted and Unpolluted Quiescent Waters, with two degrees of pollution.

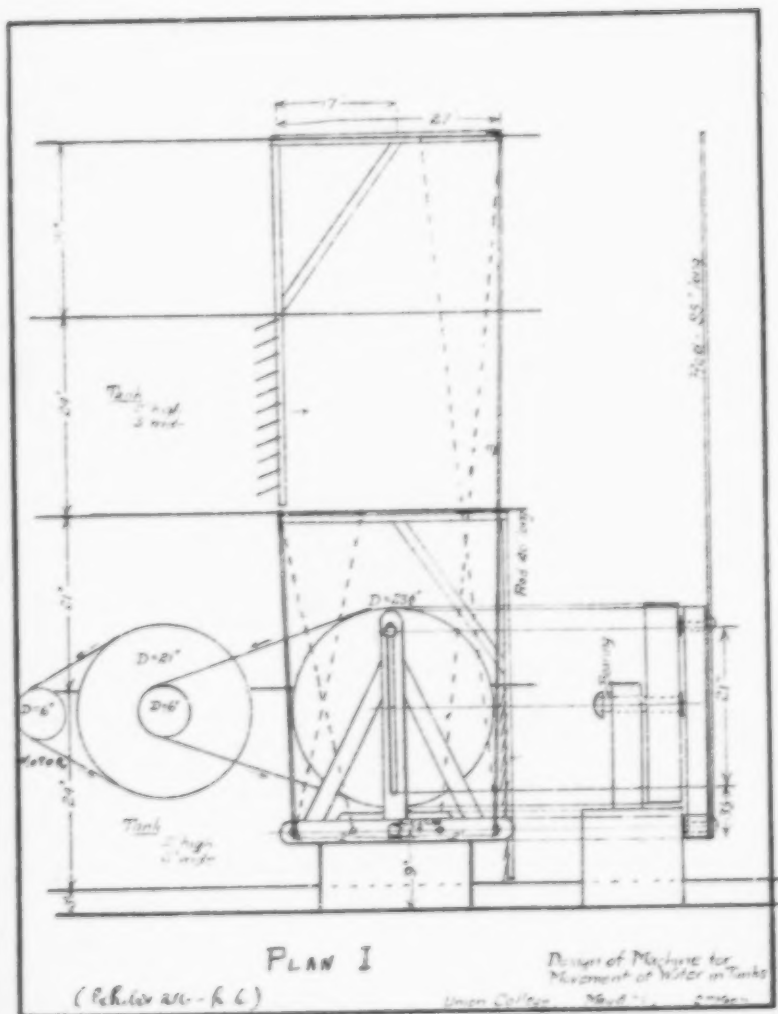
III. Polluted and Unpolluted Moving Waters, with two degrees of pollution.

This work involved a total of 700 oxygen determinations.

(Here follow two diagrams marked Exhibit 216, pages 5 and 6.)







The Apparatus.

Two elliptical tanks, built one above the other as shown in the accompanying photograph, are used to contain the water under examination. The curved ends are semicircles of $7\frac{1}{2}$ foot radius and the straight sides are 13 feet long. The width of the tanks is 3 feet and the depth of the water 2 feet. The cubical content of each tank is therefore 438.74 cubic feet, or 3,282 gallons.

The apparatus for keeping the water in motion, the levers of which are shown at the right of the photograph, was devised by Professor O. H. Landreth, to whom the grateful appreciation of the author is heartily given for his constant and valuable advice and supervision of the work. The details of the apparatus are shown in Plan I. Each tank is provided with a wing, extending across the entire width, which consists of a frame and shutters, so constructed that at the forward movement the shutters are closed, thus pushing the water ahead, and at the return movement are open, thus offering little resistance to the water. By swinging these wings backward and forward, the water is given a flowing motion around the tank, and, as the shutters are entirely immersed in the water, all aeration due to spluttering is avoided.

Plan I also shows the propelling device. The wing of the upper tank is attached by a long arm to the right extremity of the "T", and that of the lower tank by a shorter arm to the left extremity of the "T". The "T" is provided with a slot in which the button
8 attached to the wheel moves up and down with each revolution of the wheel, thus giving the cross-arm of the "T" a motion similar to the walking beam of a steamer, and causing the wings to swing back and forth. The whole is attached by an intermediate shaft to a motor. The dotted lines in the plan show how, by attaching the rods at different places on the "T" and on the arms of the wings, different rates of velocity are obtained.

Owing to circumstances not under our control, the electric motor intended for use as a propelling power was not delivered at our laboratory in time to be available for this series of observations, and we were compelled to resort to hand power. This was placed at the end of the long lever shown in the photograph between the two tanks, and the wings were attached to each other by one long arm. The velocity of the water around the tank was measured at intervals, and it is believed the average thus obtained represents the real velocity of the water during the days on which observations on moving water were taken.

The object of having two tanks is obvious. With one containing salt water and the other fresh water, for instance, whatever the atmospheric conditions, both will be under the same conditions and subject alike to whatever change may take place in these conditions during any period of observation. As to the size of the tanks, it is our desire to study as large a volume of water as our facilities allow, and the apparatus was set up in the Hydraulic Laboratory of the General Engineering Building of Union College.

9 Humidity measurements were made by means of an improved form of Hygrodek manufactured by the Taylor Instrument Company of Rochester, N. Y. It consists of two thermometers (wet and dry bulb) mounted on the outer edges of a chart, plotted from new and corrected tables prepared under the direction of the United States Weather Bureau.

Temperatures were read from accurate chemical thermometers, in Centigrade degrees. The thermometers were suspended in and over the waters in each tank. For the convenience of those who are not accustomed to the Centigrade scale, the temperature readings are given in the tables as Fahrenheit degrees. It will be at once apparent from those readings that our experiments were conducted under summer conditions.

Atmospheric pressure was read from the ordinary mercury column barometer, graduated to give accurate readings to 1/100 of an inch.

10

Methods of Operation.

Each series of observations was begun by filling the tanks with water to within three or four inches of the top. When salt water was to be used, a measured quantity of salt was added. Live steam was led into the water until the temperature stood at about 60 degrees Centigrade. The valve controlling the steam jets is shown in the right of the photograph, just above the upper tank. The rate of absorption of oxygen by quiescent water is so slow that, by the time the water had cooled to room temperature, when observations were begun, a condition of 50% to 60% saturation was easily obtainable by this method. At the time of the last series, the college steam plant was not in operation, and advantage was taken in this case of the fact that the Schenectady water runs low in dissolved oxygen. It will be seen that that set of observations does not have so low a starting point as the previous ones.

Sewage for polluting the waters was taken from one of the manholes of the city sewers, just outside one of the entrances to the Union College grounds. Sewers come to this manhole from three directions, but all of them from residential portions of the city. The sewage used in these experiments was, therefore, entirely free from factory or trade wastes. Samples were collected between 7 A. M. and 8 A. M. in each instance, a period when the flow past this special manhole is larger than at any other hour of the day.

11 The method of determining dissolved oxygen used for these experiments was the so-called Levy Method, which investigation in this laboratory in 1912 showed to be more dependable than other well known methods, when water contains a large amount of nitrites. The reagents are as follows:

Ferrous Sulfate:

144 grams Kohlbaum's crystallized ferrous sulfate, 15 c. c. concentrated sulfuric acid, and 3 liters of water.

Sodium Carbonate:

100 grams in 1 liter of water.

Sulfuric Acid:

Equal parts of concentrated acid and water Potassium Permanganate.

25.4 grams to 4½ liters of water.

This reagent was standardized against Sodium Oxalate obtained from the Bureau of Standards, Washington, D. C.

In place of the usual pipetter, burettes especially designed by this laboratory and made by Emil Greiner Company, New York, were used for measuring the reagents. The burettes were calibrated in accordance with the regulation of the United States Bureau of Standards.

The sampling bottles were of about 500 c. c. capacity, and three samples were taken for every determination, one for a blank and one for a check. The samples were drawn from "mid-stream" and at the middle depth. A siphon of small glass tubing was used for the purpose, and was securely fastened in place in each tank, to insure a sample from the same point for each determination.

Outline of Plan of Observation.

- I. A study of salt and fresh quiescent water.
- II. A study of polluted and unpolluted quiescent salt water, with varying degrees of pollution.
- III. A study of polluted and unpolluted, moving salt water with varying degrees of pollution.

SERIES I.

Comparison of Unpolluted, Quiescent Fresh and Salt Water.

For this series, the upper tank was filled with fresh water and the lower tank with the same water to which salt was added sufficient to give a salinity of 11.341.6 parts chlorine per million, or a little in excess of 60% of the salinity of sea water. The series ran through seven days, Sunday intervening, on which no determinations were made. The first day, samples were taken every hour, but the rate of absorption proved to be so slow that throughout the succeeding days samples were taken at intervals of three hours.

In this series as in all the others, air and water temperatures, humidity and barometer readings were taken with each sample. These readings are recorded in Table I. The curves for the amount of oxygen per liter are given in Diagram I, and a comparison of Oxygen and Humidity curves for both waters are given in Diagrams II and III.

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TABLE I.

Oxygen Absorption by Fresh and Salt Waters Under the Same Conditions.

Salt. c. c. oxygen per l.	Fresh.	Time.	Humid- ity, %	Barome- ter, in.	Temp. air.	Temp. water.
2.439	.....	11 A. M., Sat.	48.5	29.85	72.5	71.6
.....	2.867	"	"	"	74.	71.
2.666	.....	12 M.	39	"	71.6	72.5
.....	2.714	"	"	"	73.	71.
2.666	.....	1 P. M.	37.5	"	71.6	72.5
.....	2.641	"	"	"	73.4	69.8
2.666	.....	2 P. M.	44	"	74.	71.6
.....	2.993	"	"	"	74.	69.8
2.714	.....	3 P. M.	45	29.86	71.6	72.5
.....	2.791	"	"	"	73.4	69.8
2.538	.....	4 P. M.	46	29.84	71.	71.6
.....	2.917	"	"	"	72.5	69.8
2.791	.....	5 P. M.	44	"	69.8	71.6
.....	2.703	"	"	"	72.5	69.8
4.049	.....	11 A. M. Mon.	49	"	71.	64.4
.....	3.373	"	"	"	72.5	66.2
3.514	.....	4 P. M.	55.5	"	64.4	64.4
.....	3.513	"	"	"	66.2	67.
3.658	.....	8 A. M. Tues.	47	30.13	67.	62.6
.....	3.731	"	"	"	71.	64.4
3.810	.....	11 A. M.	43	30.03	71.6	64.6
.....	3.986	11 A. M.	43	"	73.4	65.5
3.963	.....	2 P. M.	34	30.02	72.5	64.4
.....	3.782	"	"	"	75.2	66.2
3.785	.....	5 P. M.	39.5	30.04	73.4	64.4
.....	3.782	"	"	"	75.2	66.2
3.790	.....	8 A. M. Weds.	37.5	30.22	69.	64.
.....	4.119	"	"	"	72.5	66.2
4.074	.....	11 A. M.	"	"	71.6	65.5
.....	4.707(*)	"	"	"	74.5	66.2
3.947	.....	2 P. M.	37.5	"	73.4	64.4
.....	4.094	"	"	"	77.	67.
4.049	.....	5 P. M.	41.5	30.24	69.	64.4
.....	4.042	"	"	"	72.5	67.
3.998	.....	8 A. M. Thursday..	40.5	30.34	69.8	64.
.....	3.698	"	"	"	72.5	66.2
4.048	.....	11 A. M.	"	30.33	73.4	64.4
.....	4.098	"	"	"	76.	67.
4.303	.....	2 P. M.	36.5	30.29	73.4	64.4
.....	3.946	"	"	"	75.2	68.
4.196	.....	5 P. M.	38.5	30.23	69.8	64.4
.....	3.698	"	"	"	72.5	68.
3.727	.....	8 A. M. Friday....	40.6	30.12	71.6	64.4
.....	4.121	"	"	"	73.4	67.
3.307	.....	11 A. M.	48	30.05	73.4	65.5
.....	4.394	"	"	"	75.2	67.
2.838	.....	2 P. M.	50.5	30.01	72.5	65.5
.....	3.973	"	"	"	76.	68.
3.752	.....	5 P. M.	56	29.95	69.8	65.5
.....	4.170	"	"	"	72.5	68.

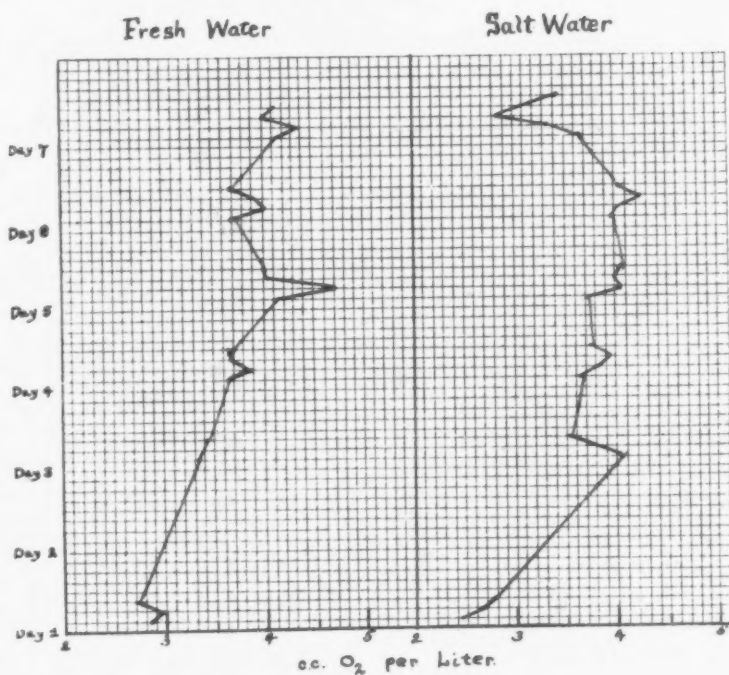
Salinity, 11,341.6 parts Chlorin per million.

(Here follow three diagrams marked Exhibit 216, pages 15, 16, 17.)

Diagram I.

Oxygen Curves, Fresh and Salt Water.

April 5-11, 1913.



(Exhibit No 246-p. 15)

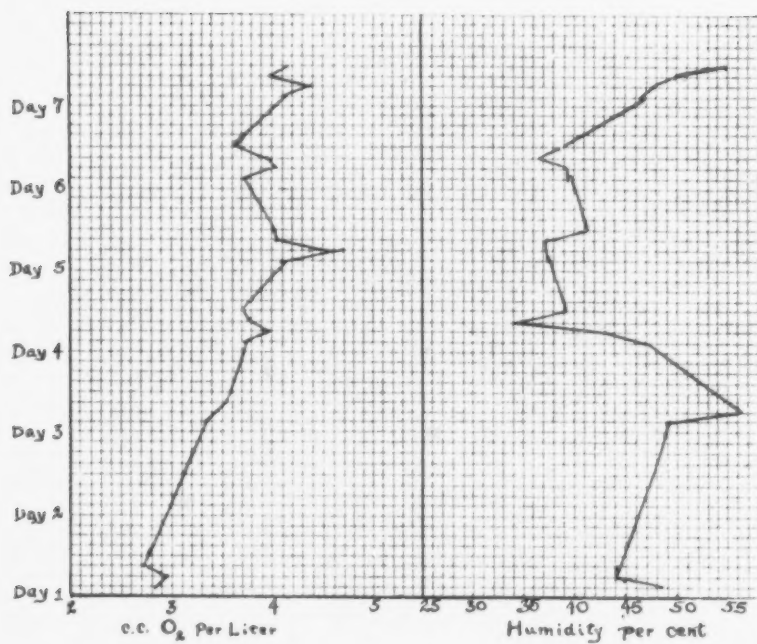


Diagram II

Humidity and Oxygen Curves.

Fresh Water

April 5-11, 1913, inclusive



(Exhibit No 216, p. 16)

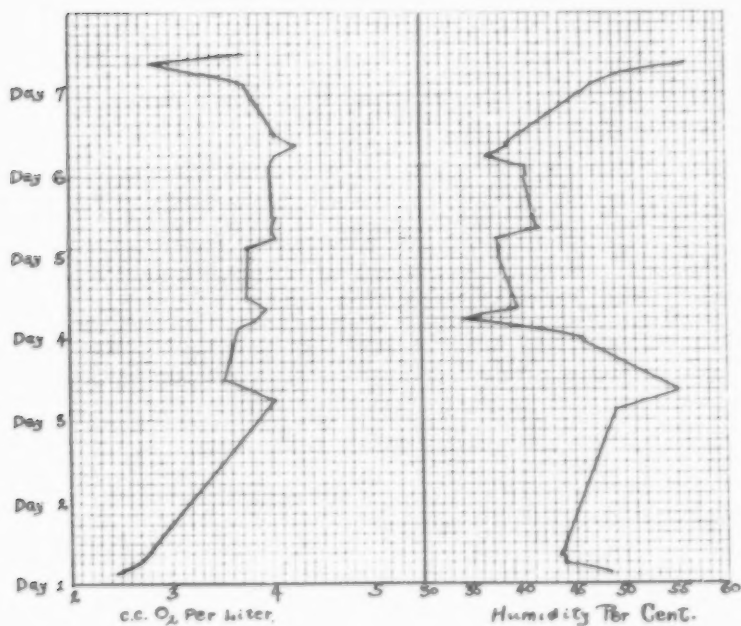
Diagram III

Humidity and Oxygen Curves.

Salt Water

11,341.6 parts chlorine
per million

April 5-11, 1913, inclusive.



(Exhibit No. 216. & 17)

Some of the Results.

1. Increase of oxygen per liter from first reading of first day to last reading of last day,

Salt water.....	1.313 c. c.
Fresh water.....	1.303 c. c.

Average rate of increase per day,

Salt water.....	0.1877 c. c.
Fresh water.....	0.1861 c. c.

If sea water of this salinity, namely 11,341.6 parts Chlorine per million, i. e., approximately 61% sea water, contains at this temperature 5.9 c. c. oxygen per liter at saturation, and fresh water at this temperature contains 6.482 c. c. oxygen per liter at saturation, the above increase, in terms of per cent, is—

Salt Water, from 41% to 63%, total 22%.
Fresh Water, " 44% " 64%, " 20%.

2. Examination of Diagram I shows that, whatever may be the cause of the fluctuations, it affects both waters in the same way, for, in general, the curves break in the same direction. On these seven days, the changes of less than 1/10 of an inch in pressure and of about 1/2 degree Centigrade in temperature indicate practically constant conditions. But humidity changes are more perceptible, and reference to Diagrams II and III shows at four points, at least, that where humidity increased, on Day 1, Day 4, Day 5 and Day 6, oxygen content increased.

Some General Conclusions.

While salt water contains less oxygen at saturation than fresh water, both seem to absorb oxygen at the same rate, between 40% and 60% of saturation.

The absorption of oxygen by both fresh and salt water, is not so rapid as has been supposed, being in this instance about 0.18 c. c. per day, or about 3% of saturation value per day.

The effect of humidity is suggested by the results of the determinations; the greater the humidity, the less the absorption. Further investigation along this line will be carried out in this laboratory.

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TABLE II.

Oxygen Absorption by Polluted and Unpolluted Salt Water Under the Same Conditions.

Polluted. c. c. oxygen per liter.	Unpolluted.	Time.	Humid- ity, %.	Barome- ter, in.	Temp. air.	Temp. water.
2.924	.....	11 A. M.	30.0	29.81	64.4	80.6
.....	3.384	.....	"	"	69.8	78.8
2.924	.....	2 P. M.	44	"	66.2	78.8
.....	2.750	"	"	"	69.8	78.8
3.086	.....	5 P. M.	43.5	29.79	65.5	75.2
.....	2.934	"	"	"	71.6	78
.....	2.909	8 A. M.	47.5	29.88	74.5	74.5
2.644	.....	11 A. M.	40.0	29.79	71	71.6
.....	3.384	11 A. M.	40.0	"	72.5	73.4
2.621	.....	2 P. M.	41.5	29.72	71.6	71
.....	3.437	"	"	"	72.5	72.5
2.643	.....	5 P. M.	42.5	29.68	71.6	71
.....	3.567	"	"	"	73.4	73.4
2.545	.....	8 A. M.	40.0	29.55	73.4	69.8
.....	3.955	"	"	"	75.2	71.6
2.908	.....	11 A. M.	35	29.61	66.2	69.8
.....	3.921	"	"	"	71	71.6
2.924	.....	2 P. M.	41	29.79	67	69
.....	4.055	"	"	"	69	71
2.840	.....	5 P. M.	42	29.76	67	69
.....	4.115	"	"	"	68	69.8
One day (Sunday) intervening.						
3.485	.....	8 A. M.	48	30.23	67	64
.....	4.377	"	"	"	69	64.4
3.465	.....	11 A. M.	39	30.20	64.4	64
.....	4.668	"	"	"	68	64.4
4.143	.....	2 P. M.	38	30.18	73.4	64.4
.....	5.034	"	"	"	74.5	65.5
4.204	.....	5 P. M.	34.5	30.15	63.5	64.4
.....	4.612	"	"	"	66.2	64.4

Salinity, polluted water, 13,309.8.

Salinity, unpolluted water, 12,684.8.

Pollution, 1 gallon of sewage to 60 gallons of water.

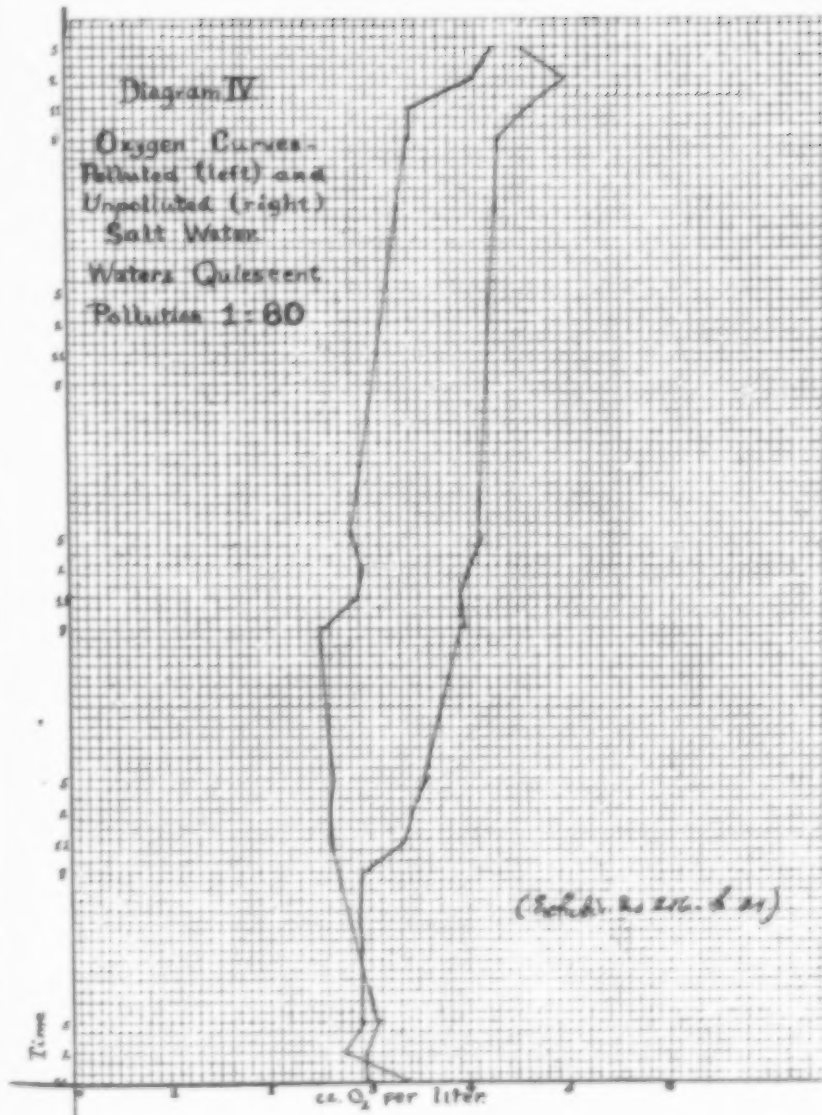
(Here follow three diagrams marked Exhibit No. 216, pages 21, 22, and 23.)

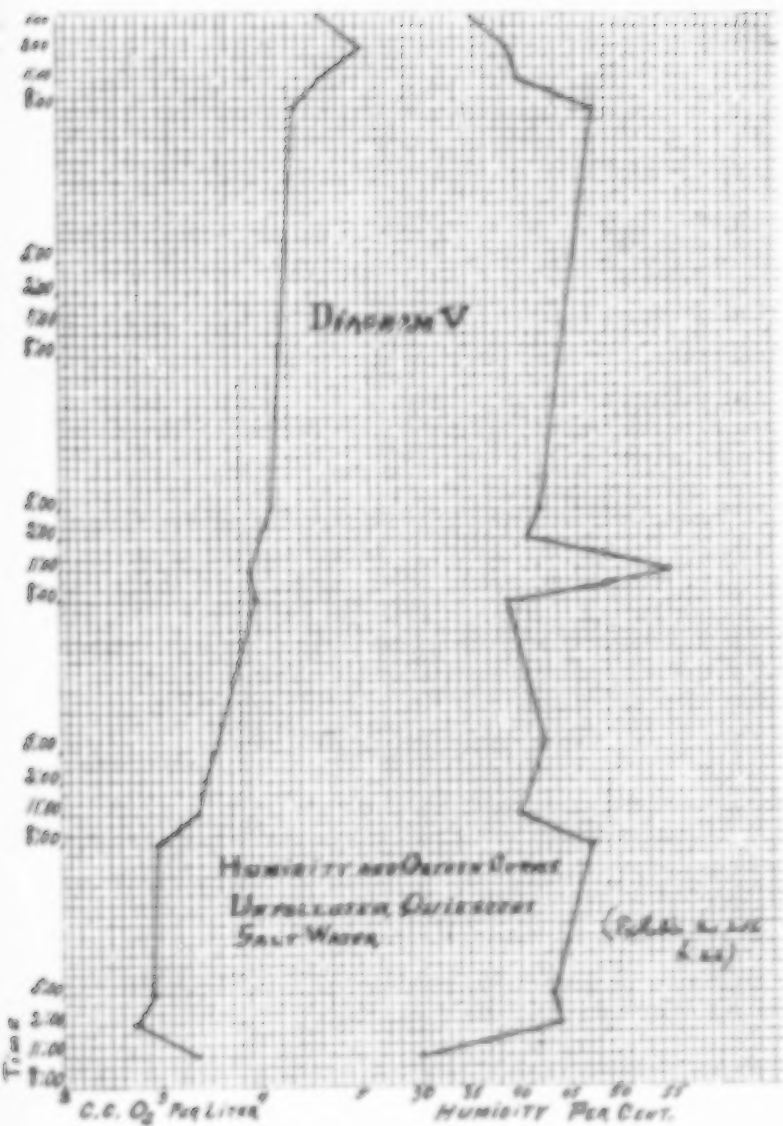
Diagram IV

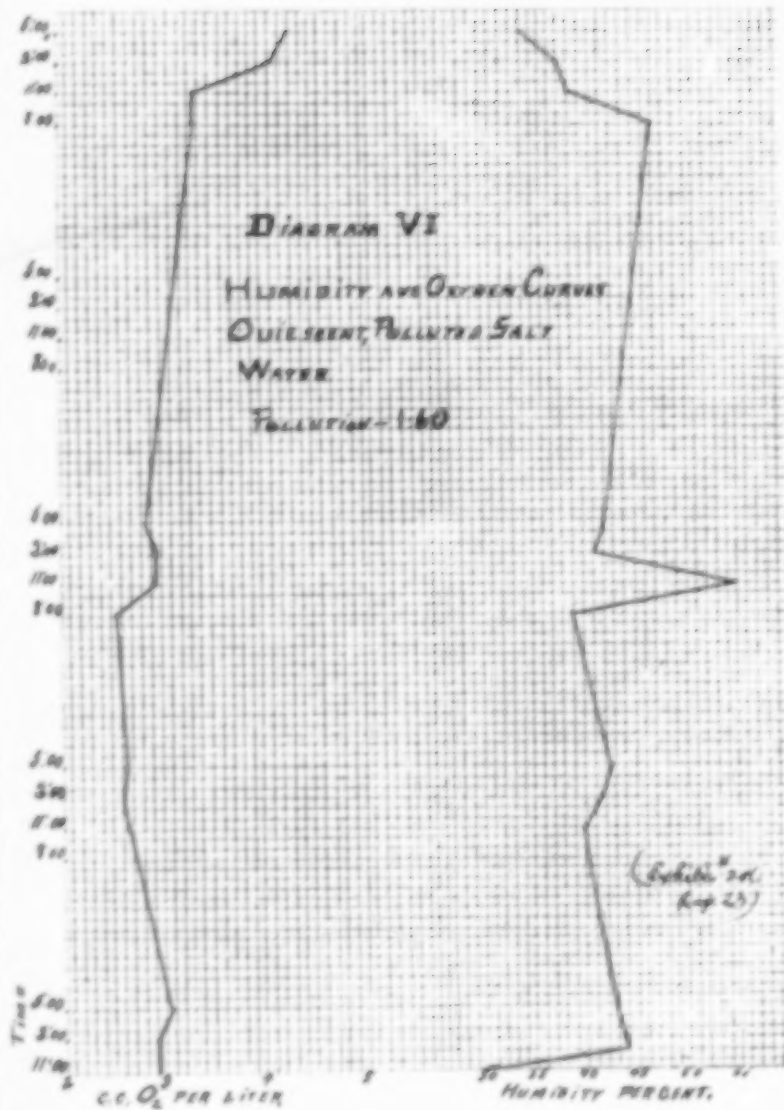
Oxygen Curves -
Polluted (left) and
Unpolluted (right)
Salt Water

Waters Quiescent

Pollution 1:60







SERIES II.

Comparison of Polluted and Unpolluted Quiescent Salt Waters.

A.

For this series, the upper tank was filled with salt water, salinity 12,684.83 parts Chlorine per million, or approximately 68% sea water, and the lower tank with salt water, salinity 13,309.8 parts chlorine per million, or approximately 72% sea water. To the water in the lower tank, after cooling from heating, 55 gallons of sewage was added, giving approximately a proportion of sewage to water of one to sixty (1:60). Determinations of dissolved oxygen were begun immediately following the addition of the sewage, and samples were taken at three hour periods for five days. Readings are given in Table II and curves in Diagrams IV and V.

Some of the Results.

1. Increase of oxygen per liter from first reading of first day to last reading of last day,

Unpolluted Salt Water.....	1.226 c. c.
Polluted Salt Water.....	1.380 c. c.

Average rate of increase per day,

Unpolluted Salt Water.....	0.245 c. c.
Polluted Salt Water.....	0.276 c. c.

If the salt water of the salinity of the polluted water contains 5.68 c. c. oxygen per liter, at the temperature of this series, and salt water of the salinity of the unpolluted water contains 5.7 c. c. oxygen per liter at this temperature, the above increases in terms of per cent are—

25	Unpolluted Salt Water, 59% to 80%, total 21%.
	Polluted Salt Water, 51% " 75%, " 24%.

2. The curve given in Diagram IV shows that the first two days the curves diverge, the polluted water showing decreasing oxygen. Beginning at eight o'clock on the third day, and continuing two days, there is a steady increase of oxygen in both waters.

3. Comparison of the humidity and oxygen curves shows what Diagrams II and III show, namely, when humidity increases, oxygen decreases. The variations in any two successive readings of barometer and water temperature are very slight. This seems to indicate the effect of humidity.

4. The greater rate of absorption in this series as compared with

Series I is difficult to account for. The average humidity in both series is about the same, 43.6 in the first and 42.4 in the second. The barometric readings are approximately the same in the two series, and there is not a great deal of difference in the water temperatures on the Centigrade scale. The salinity varies a little, but the difference does not seem great enough to account for the greater rate of absorption.

Some General Conclusions.

The absorption of oxygen by salt water may under certain conditions reach the average rate of 0.276 c. c. per liter per day.

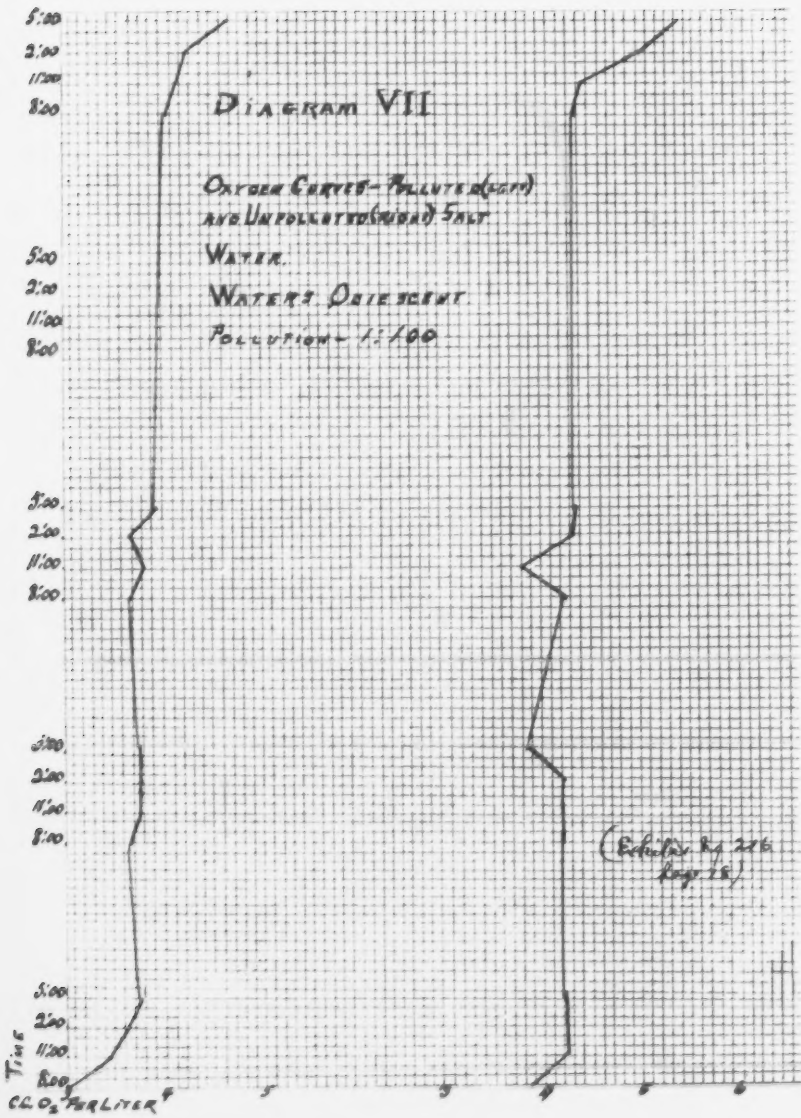
When quiescent salt water is polluted with sewage at a dilution of one to sixty, the first effect is a decrease of the oxygen content, but after two days, the rate of absorption is quite as rapid as that of unpolluted salt water. It would seem then, that a dilution in this proportion is not permissible in quiescent salt water.

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TABLE III.

Oxygen Absorption by Polluted and Unpolluted Salt Water Under the Same Conditions.

Polluted. c. c. oxygen per L.	Unpolluted.	Time.	Humid- ity, %.	Barome- ter, in.	Temp. air.	Temp. water.
3.040	.....	8 A. M.	81	30.08	66.2	68
.....	3.891	"	"	"	68	66.2
3.485	.....	11 A. M.	66.5	30.07	71	67
.....	4.234	"	"	"	71	66.2
3.625	.....	2 P. M.	53	30.03	73.4	66.2
.....	4.234	"	"	"	73.4	67
3.780	.....	5 P. M.	"	30.01	73.4	67
.....	4.234	"	"	"	71.6	68
3.683	.....	8 A. M.	49	30.02	71.6	68
.....	4.211	"	49	"	71.6	68
3.789	.....	11 A. M.	60	30.01	71.6	68
.....	4.119	"	"	"	71.6	68
3.789	.....	2 P. M.	61	29.96	72.5	68
.....	4.234	"	"	"	72.5	69
3.789	.....	5 P. M.	62	29.97	72.5	68
.....	3.891	"	"	"	71.6	69
3.683	.....	8 A. M.	77	29.95	69	68
.....	4.257	"	"	"	69.8	69
3.800	.....	11 A. M.	63	29.92	71	69
.....	3.799	"	63	"	71	69
3.683	.....	2 P. M.	54	29.89	73.4	68
.....	4.325	"	"	"	73	69
3.952	.....	5 P. M.	49	29.88	71.6	66.2
.....	4.871	"	"	"	71.6	68



One day (Sunday) intervening.

Polluted, c. c. oxygen per L.	Unpolluted.	Time.	Humid- ity, %.	Barome- ter, in.	Temp. air.	Temp. water.
4.092	.....	8 A. M.	83	29.61	64	66.2
.....	4.394	"	"	"	66.2	68
4.139	.....	11 A. M.	75	29.58	65.5	66.2
.....	4.554	"	"	"	66.2	66.2
4.256	.....	2 P. M.	82	29.57	63.5	66.2
.....	5.057	"	"	"	66.2	68
4.677	.....	5 P. M.	76	29.56	63.5	66.2
.....	5.424	"	"	"	66.2	67

Salinity, polluted water, 13,610.7 parts chlorin per million.

Salinity, unpolluted water, 11,897.8 " " "

Pollution, 1 gallon sewage to 100 gallons water.

(Here follows diagram marked Exhibit No. 216, page 28.)

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SERIES II.

Comparison of Polluted and Unpolluted Quiescent Salt Waters.

B.

For this series, the upper tanks was filled with salt water, of the salinity of 13,610.7 parts Chlorine per million, approximately 73% sea water, and the lower tank with salt water of the salinity 11,897.8 parts Chlorine per million, or approximately 64% sea water. To the water in the lower tank, after cooling from heating, approximately 30 gallons of sewage was added, giving a dilution of one to one hundred. Dissolved oxygen content was determined immediately after the addition of the sewage, and at three hour periods thereafter for five days. The readings are given in Table III and the curves in Diagram VII.

Some of the Results.

1. Increase of oxygen content per liter from first reading of first day to last reading of last day,

Unpolluted Salt Water.....	1.533 c. c.
Polluted Salt Water.....	1.637 c. c.

Average rate of increase per day,

Unpolluted Salt Water.....	0.306 c. c.
Polluted Salt Water.....	0.327 c. c.

2. The curves given in Diagram VII show a very slight divergence after the first day and to the beginning of the third day. It would seem therefore, that a dilution of pollution of 1:100 was about what quiescent salt water of that salinity will stand.

30 3. If fluctuations are due to humidity, it is not so apparent in this series as in the first two. At one point in each of the five days, an increase in oxygen content was accompanied by a decrease in humidity; but at other points the oxygen content remained constant, or the change was in the same direction as the change in humidity.

Some General Conclusions.

The absorption of oxygen by quiescent salt water may, under certain conditions, reach the average of 0.306 c. c. per day. Quiescent salt water seems to be able to take care of pollution of one gallon of sewage to 100 gallons of salt water.

TABLE IV.

Oxygen Absorption by Polluted and Unpolluted Water in Motion Under the Same Conditions.

Polluted. c. c. oxygen per L.	Unpolluted.	Time.	Humid- ity. %.	Barome- ter, in.	Temp. air.	Temp. water.
4.600	.....	8 A. M.	48.5	29.90	58	55.4
.....	5.143	"	"	"	60.8	55
5.0478	.....	9 A. M.	40	29.91	60	55.4
.....	5.149	"	"	"	60.8	55
4.989	.....	10 A. M.	47	"	59	55.4
.....	5.149	"	47	"	60.8	55
5.165	.....	12 M.	43.5	29.85	62	55.4
.....	5.264	"	"	"	62.6	55
4.989	.....	1 P. M.	37	29.83	64.4	56.5
.....	5.434	1 P. M.	"	"	64.4	54.5
5.048	.....	2 P. M.	43	29.82	64.4	55
.....	5.618	"	"	"	64.4	55
4.938	.....	3 P. M.	34.5	29.82	64.4	55
.....	5.604	"	"	"	64.4	55
5.228	.....	4 P. M.	36	"	64.4	53.6
.....	5.604	"	"	"	64.4	53.6
4.932	.....	8 A. M.	59.5	29.74	59	55.4
.....	5.584	"	"	"	56.5	56.5
4.711	.....	9 A. M.	65	29.72	60	55.4
.....	5.744	"	"	"	57.2	56.5
5.048	.....	10 A. M.	57	29.68	60.8	55.4
.....	5.607	"	"	"	60.8	57.2
4.874	.....	11 A. M.	55	"	60.8	55.4
.....	5.607	"	"	"	60.8	57.2
4.816	.....	1 P. M.	62	29.64	62.6	55.4
.....	5.584	"	"	"	63.5	57.2
4.816	.....	2 P. M.	51	"	64.4	55.4
.....	5.813	"	"	"	64.4	57.2
4.758	.....	3 P. M.	58	29.68	64.4	55.4
.....	5.906	"	"	"	64.4	57.2
4.932	.....	4 P. M.	61	29.71	62.6	55.4
.....	5.950	"	"	"	62.6	57.2
5.106	.....	5 P. M.	62	"	62.6	55.4
.....	5.927	"	"	"	62.6	57.2

Salinity, polluted water, 13,340 parts chlorine per million.

Salinity, unpolluted water, 12,730 " " " "

Pollution, 1 gallon sewage to 60 gallons water.

Velocity, 1 foot per second.

(Here follows diagram marked Exhibit No. 216, page 32.)

Comparison of Polluted and Unpolluted Salt Water in Motion.

A.

For this series the upper tank was filled with salt water, of the salinity 12,730 parts Chlorine per million, or approximately 68% sea water, and the lower tank was filled with salt water of the salinity of 12,340 parts Chlorine per million, or approximately 72% sea water. To the water in the lower tank approximately 55 gallons of sewage was added, giving a solution of approximately 1:60, the same dilution as in Series IIA, where the waters were quiescent. Oxygen and other determinations were begun immediately after the sewage was added, the water set in motion at a velocity of 1 foot per second, and determinations were made every hour. The readings are recorded in Table IV and the curves in Diagram VIII.

Some of the Results.

1. Increase in oxygen content per liter from beginning of first day to end of first day,

Unpolluted Salt Water.....	0.515 c. c.
Polluted Salt Water.....	0.523 c. c.

Increase in oxygen content per liter from beginning of second day to end of second day,

Unpolluted Salt Water.....	0.343 c. c.
Polluted Salt Water.....	0.174 c. c.

2. The curves show the general tendency to increase of oxygen content in both polluted and unpolluted waters, while the rate of both in the second day is less than the first, and that of the polluted water much less, from the starting point of each day there is an increase toward the end of the day. During the night between the two days, when the waters were quiescent, the reduction in oxygen content of the polluted water was more marked than in the unpolluted water, but soon after the water began to move there was an increase in the oxygen content.

3. During the first day the humidity ranged from 48.5 in the morning to 36.0 in the afternoon, while during the second day it ranged from 59.5 in the morning to 62 in the evening, thus being greater on the second day, when the rate of absorption was less.

Some General Conclusions.

Unpolluted salt water moving at the rate of one foot per second, compared with quiescent, unpolluted salt water, shows rates of increase in oxygen content per day as follows:

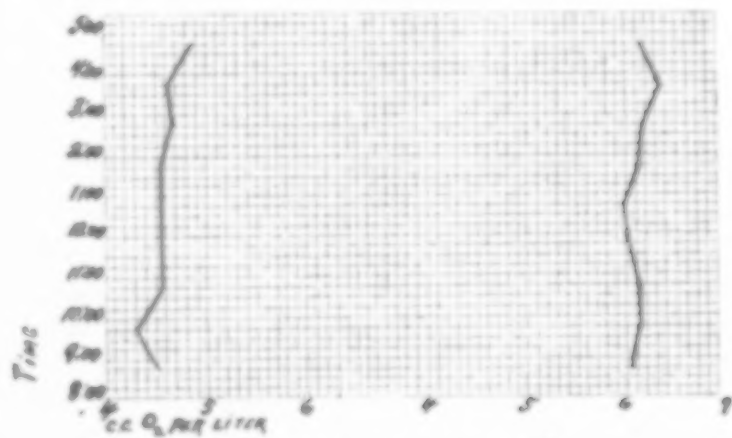
Diagram IX

OXYGEN CURVES- Polluted (left)
and Unpolluted (right) Salt
Water

Velocity = 1 ft. per second

Pollution = 1:30

(Unpolluted continuation of Diagram VIII)



(Refer to page 36)

Quiescent unpolluted salt water.....	0.245	Series	IIA
" " " "	0.306	"	IIB
Moving " " " "	0.389	"	IIIA

Polluted salt water, moving at the rate of one foot per second, compared with quiescent salt water of the same degree of pollution, namely 1:60, shows rates of increase per day as follows:

	First day.	Second day.
Quiescent, Polluted Salt Water.....	0.162 c. c.	no change
Moving Polluted Salt Water.....	0.523	0.174

It would therefore seem that a salt water moving at the rate of one foot per second could take care of more sewage than quiescent salt water.

E

TABLE V.

Oxygen Absorption by Polluted and Unpolluted Water in Motion Under the Same Conditions.

Polluted, Unpolluted, c. c. oxygen per L.	Time.	Humid- ity, %.	Barome- ter, in.	Temp. air.	Temp. water.
4.528	8 A. M.	69	29.96	60.8	55.4
..... 6.095	"	"	"	57.2	58
4.254	9 A. M.	61.5	"	60.8	55.4
..... 6.122	"	"	"	60.8	57.2
4.572	10 A. M.	59	29.96	60.8	55.4
..... 6.123	"	"	"	60.8	57.2
4.584	12 M.	53	29.96	62.6	55.4
..... 5.990	"	"	"	63.5	58
4.584	1 P. M.	43.5	"	65.5	55.4
..... 6.122	"	43.5	"	64.4	58
4.608	2 P. M.	41.5	"	65.5	55.4
..... 6.179	"	"	"	65.5	58
4.642	3 P. M.	47	"	62.6	55.4
..... 6.351	"	"	"	63.5	58
4.674	4 P. M.	37	"	58	55.4
..... 6.179	"	"	"	63.5	57.2

Salinity, polluted water, 13,000 parts chlorine per million.
Unpolluted water continuation of water used in Table IV.
Pollution, 1 gallon sewage to 30 gallons water.
Velocity, 1 foot per second.

(Here follows diagram marked Exhibit No. 216, page 36.)

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SERIES III.

Comparison of Polluted and Unpolluted Salt Waters in Motion.

B.

For this series the upper tank was not changed, and the lower tank was filled with salt water of the salinity of 13,030 parts Chlorine per million and approximately 100 gallons of sewage were added. Oxygen and other readings were begun immediately and the water set in motion at the rate of one foot per second. The readings are given in Table V and the curves in Diagram IX.

Some of the Results.

Increase in oxygen content in one day, in the polluted water, is 0.348 c. c. Compared with the first day of other polluted salt waters, we get the following:

				Increase 1st day.
Quiescent, polluted salt waters	(1:60)	.....		0.162 c. c.
Moving	" " "	(1:60)	.....	0.523 c. c.
"	" " "	(1:30)	.....	0.348 c. c.

It would appear that moving salt water can take care of a large quantity of sewage, if the sewage can be evenly distributed through it.

THE PEOPLE OF THE STATE OF NEW YORK,
COMPLAINANTS,

VS.

STATE OF NEW JERSEY ET AL.

Here Follow

DEFENDANTS' EXHIBITS

Nos. 4, 6, 7.

JAMES D. MAHER,
Commissioner.